The Journal of Thoracic Surgery

VOL. 19 JUNE, 1950 NO. 6

Original Communications

BRONCHOSPIROMETRY IN THE LATERAL DECUBITUS POSITION

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INTRODUCTION

SINCE the original work by Jacobaeus[1] and the development by Gebauer[2] and Zavod[3] of double lumen soft rubber bronchial catheters with occlusive balloons, bronchospirometry has become an accepted procedure for analyzing the respiratory and ventilatory functions of the individual lungs. This report is a study of bronchospirometry in the lateral decubitus position as one of a series of studies in pulmonary and respiratory physiology. It records our observations on a number of patients in whom bronchospirometry was performed in one or both lateral decubitus positions immediately after a satisfactory tracing was obtained with the patient supine. We have studied eleven patients by this method. In six we have recordings in both lateral decubitus positions, and in five in the right lateral decubitus alone. Six of these patients had uncomplicated pulmonary tuberculosis (Table I). In one there was a unilateral phrenic paralysis; one had unilateral artificial pneumothorax plus contralateral phrenic paralysis; one had a nonobstructing carcinoma of the left lower lobe bronchus; one had a mediastinal cyst; and one had had a right lower lobectomy for pulmonary tuberculosis associated with right phrenic paralysis.

TECHNIQUE

The patient is prepared by receiving 1½ gr. of pentobarbital sodium by mouth one hour before bronchospirometry. One-half hour before the procedure, a hypodermic injection of 100 mg. of demerol and $\frac{1}{75}$ gr. of atropine sulfate is administered. Anesthesia of the throat and larynx is secured by local application of 2 per cent pontocaine.

From the Tuberculosis and Surgical Services, Veterans Administration Hospital, Wood, Wis.

Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

Received for publication Aug. 22, 1949.

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With the catheter in the trachea and its tip in the left main bronchus (verified by means of fluoroscopy) the double-barreled catheter was connected to two Benedict-Roth spirometers with the tanks containing oxygen. The balloons were then inflated and a graph was obtained from each lung by means of continuous, simultaneous tracings on two revolving drums while the patient was in a supine position. Without displacing the catheter or deflating the balloons, the patient was helped to turn on the right side. A pillow was placed under the head. In all other respects the conditions remained unchanged. Readings were again taken from each lung with the patient in this position for a period of from two to five minutes. The shorter interval was used only when the respirations were smooth and uniform in size with an even slope indicating a smooth oxygen absorption curve. The patient was then assisted to roll on the left side and further graphs were secured in this position.

TABLE I

CASE	DIAGNOSIS
1	Pulmonary tuberculosis, right phrenic paralysis, left pneumothorax
2	Pulmonary tuberculosis, minimal, left
3	Pulmonary tuberculosis, far advanced, left lung only
4	Pulmonary tuberculosis, minimal, right
5	Carcinoma, left lower lobe bronchus
6	Pulmonary tuberculosis, minimal with left phrenic paralysis
7	Mediastinal cyst, right
8	Pulmonary tuberculosis, moderately advanced, bilateral
9	Pulmonary tuberculosis, far advanced, predominantly right-sided
10	Pulmonary tuberculosis, post right lower lobectomy and right phrenic paralysis
11	Pulmonary tuberculosis, far advanced, predominantly right-sided

The total oxygen consumption (the amount used per minute by both lungs) and the differential oxygen consumption of the right and left lungs, the total tidal air and its division between the two lungs, the ventilation equivalents, and in some cases the vital capacities of each lung were compared with the patient supine and in the right and left lateral decubitus positions. In making these comparisons, the slope of the graph (see Fig. 1) was used to determine the oxygen absorption. In making tidal air determinations, consecutive, individual respirations were measured with calipers over a two- or three-minute interval. Identical respirations by the right and left lungs were thus measured and an average determined for each lung.

Not all patients who have bronchospirometric studies are suitable for these special determinations. As the procedure is prolonged there may be increasing cough and secretion, and in some the catheter becomes partly dislodged as the patient is turned on the side. The nervous temperament of the patient and his willingness to cooperate are important factors in securing satisfactory tracings.

RESULTS

Application of logic to our knowledge of pulmonary and respiratory anatomy and physiology would seem to dictate that the lung which is down should do less of the breathing. Our results, however, would indicate that exactly the opposite is true.

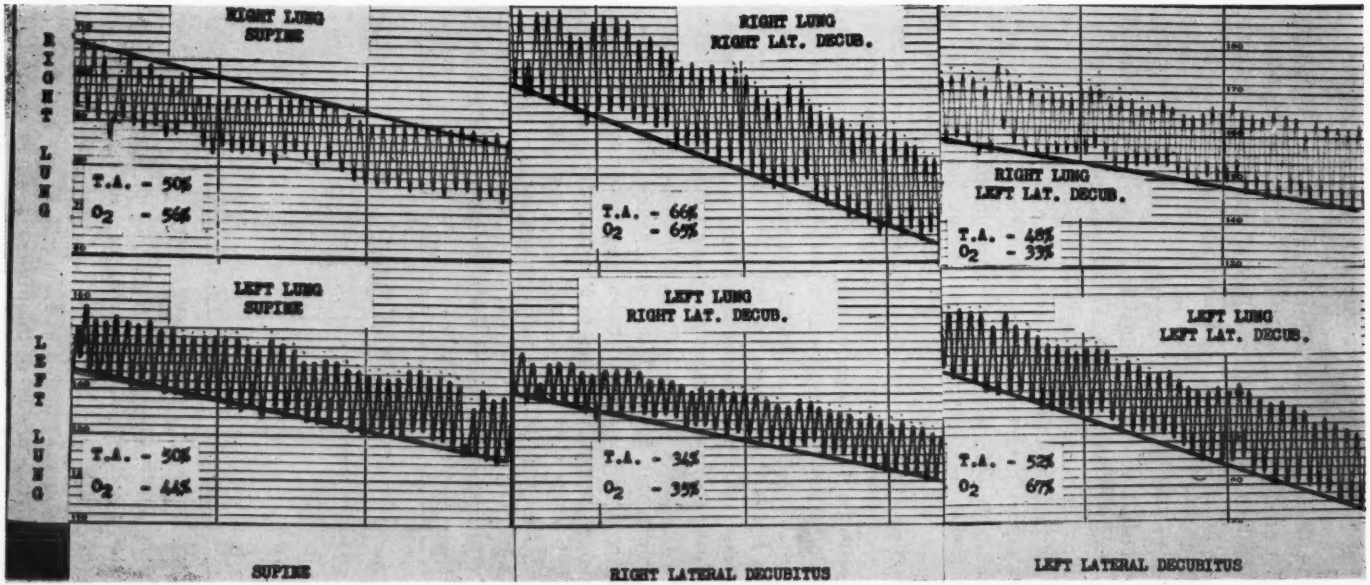

Fig. 1.—Graphs are shown of bronchospirometric readings made on one patient in the supine, the right lateral decubitus, and left lateral decubitus positions. With the patient in the supine position, the right lung performed 50 per cent of the total ventilation and 56 per cent of the total oxygen absorption. When the patient was placed on the right side, the tidal air increased to 66 per cent and the oxygen consumption to 65 per cent of the total. With the patient lying on the left side, the tidal air on the right dropped to 48 per cent of the total and the oxygen absorption dropped to 33 per per cent of the total.

Total Oxygen Consumption.—Absolute readings of oxygen consumption by both lungs are not of much value when bronchospirometry is performed because of the lack of basal conditions, the addition of sedation, and the extra effort which is needed to breathe through the bronchospirometric catheter. These conditions do not influence the proportion of the total oxygen breathed by each lung. Therefore, in most bronchospirometric studies only the relative percentage of oxygen absorbed by the individual lung is measured. However, for the purposes of this study, it was felt that the total oxygen consumption should be measured as well as the percentage absorbed by each lung so that a comparison could be made between this figure in each of the three positions (Table II). With the patient supine, the total oxygen consumption for both lungs per minute varied from 235 c.c. to 399 c.c. with an average of 303 c.c. When the subject lay upon the right side the total oxygen consumption for both lungs varied from 284 c.c. to 574 c.c., with an average of 409 c.c. The total oxygen consumption increased in every case in this position, ranging from 35 c.c. to 220 c.c., with an average increase of 103 c.c. or 34 per cent. One hundred and three cubic centimeters represented the average increase in the oxygen consumption of the right or under lung, and 3 c.c. represented the average increase in the oxygen consumption of the left lung, but there was considerable variation between individual cases. In several the oxygen consumption of the left lung showed an appreciable decrease. Six patients were studied in the left lateral decubitus position. These patients had an average oxygen consumption of 315 c.c. while supine and 343 c.c. while lying on the left side, an average increase of 9 per cent. This was due in each case to an increased oxygen absorption by the left or under lung associated with a drop in the oxygen absorption of the right lung. In all but one instance the total oxygen consumption while lying on the left side was less than that observed with the patient lying on the right side, and in two instances it was less than while he was lying supine.

TABLE II. TOTAL OXYGEN ABSORPTION IN CUBIC CENTIMETERS PER MINUTE

CASE	SUPINE	RIGHT LATERAL	LEFT LATERAL
1	286	414	
2	198	518	
3	235	394	
4	262	418	348
5	340	399	292
6	296	384	328
7	399	442	481
8	392	574	
9	231	284	
10	330	373	352
11	265	299	256
AVERAGE	303	409	343

Differential Oxygen Consumption.—This term is used to describe the proportions of oxygen used by the individual lungs. The usual findings in normal subjects with the patient supine are as follows: the right lung absorbs 55 per cent of the total oxygen consumption and the left 45 per cent with a range of 5 per cent in either direction. All of the present group studied had pulmonary

disease and mo showed alterations from this normal range even while in the supine position Table III illustrates these percentages for the patients when supine, and in ch lateral decubitus position. It will be noticed that in every instance the r lung shows a definite increase in the amount and percentage of the total oxygen consumed and that in some cases this was quite marked. The percentage absorbed by the upper lung was diminished in every case; the amount was often decreased as well.

TABLE III. DIFFERENTIAL O_2 ABSORPTION IN CUBIC CENTIMETERS PER MINUTE AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL			
	VOLUME		PER CENT		VOLUME		PER CENT		VOLUME		PER CENT	
CASE	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1*	91	195	32	68	176	238	42	58				
2	104	94	52	48	321	197	62	38				
3	111	124	47	53	235	159	60	40				
4	145	117	56	44	238	180	57	43	138	210	40	60
5	216	124	63	37	280	119	70	30	131	161	45	55
6†	166	130	56	44	249	135	65	35	107	221	33	67
7	197	202	48	52	290	152	66	34	187	294	39	61
8	192	200	49	51	388	186	68	32				
9	93	137	41	59	194	90	68	32				
10*	98	232	30	70	138	235	37	63	62	290	18	82
11	104	161	39	61	150	149	50	50	62	194	25	75

*Right phrenic paralysis.
†Left phrenic paralysis.

Total Tidal Air.—The total tidal air with the patient in the supine position averaged 636 c.c. with a range from 545 to 894 c.c. Little change in this total (Table IV) was noted with the patient in the right lateral decubitus but there was a moderate increase when he lay upon the left side (right lateral decubitus 659 c.c., left lateral decubitus 696 c.c). The respiratory rate and, therefore, the minute ventilation were essentially unchanged.

TABLE IV. TOTAL TIDAL AIR IN CUBIC CENTIMETERS PER MINUTE

CASE	SUPINE	RIGHT LATERAL	LEFT LATERAL
1	602	563	
2	623	683	
3	653	687	
4	652	649	622
5	581	681	710
6	606	650	642
7	707	663	757
8	669	698	
9	545	572	
10	894	914	883
11	467	498	560
AVERAGE	636	659	696

Differential Tidal Air (Table V).—In the normal individual the right side ventilates about 55 per cent of the total tidal air, and the left side about 45 per cent of the total. In the presence of pulmonary disease with the subject supine, the differential ventilation is usually much less affected than the oxygen consumption. An abnormal lung may contribute its normal percentage of the total ventilation. This can be seen by a comparison between the first four

columns of Tables III and V. Upon assuming the lateral decubitus position there is a much smaller change in the percentages of tidal air than in the percentages of oxygen absorption. Nevertheless, the change in every instance but two of the seventeen readings is in the same direction, that is, toward an increased percentage of ventilation by the under lung.

TABLE V. DIFFERENTIAL TIDAL AIR IN CUBIC CENTIMETERS PER MINUTE AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL			
	VOLUME		PER CENT		VOLUME		PER CENT		VOLUME		PER CENT	
CASE	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1*	281	321	47	53	290	273	52	48				
2	306	315	49	51	362	321	53	47				
3	311	342	48	52	349	338	51	49				
4	383	269	59	41	373	276	58	42	336	286	54	46
5	300	281	52	48	370	311	54	46	357	353	50	50
6†	306	300	50	50	430	220	66	34	311	332	48	52
7	340	367	48	52	363	300	55	45	367	390	48	52
8	389	280	58	42	360	338	51	49				
9	280	265	51	49	311	261	54	46				
10*	375	519	42	58	410	504	45	55	307	576	35	65
11	229	238	49	51	249	249	50	50	249	311	45	55

*Right phrenic paralysis.
†Left phrenic paralysis.

Ventilation Equivalent.—This is a numerical value which is obtained by dividing the total minute ventilation in cubic centimeters by the oxygen absorption in cubic centimeters per minute, and dividing the result by 10, and represents the number of liters of air ventilated for the absorption of each 100 c.c. of oxygen. It is a mathematical expression of the relation between ventilation and respiration and represents an index of pulmonary efficiency. The normal value is between two and three which means that ordinarily about three liters of air are breathed for 100 c.c. of oxygen absorbed. The changes from the normal values found in this study are tabulated in Table VI. In general they reflect a decrease in the ventilation equivalent for the under lung in each lateral decubitus as compared with the supine position. This is due in most cases to increased oxygen absorption with relatively less increase in the total air breathed by the under lung. With the patient lying on the left side, the

TABLE VI. VENTILATION EQUIVALENTS IN LITERS OF AIR PER 100 C.C. O_2 ABSORBED

	SUPINE		RIGHT LATERAL		LEFT LATERAL	
CASE	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
1	4.0	2.1	3.1	2.1		
2	3.4	3.9	1.4	1.9		
3	3.9	3.8	2.3	3.3		
4	4.4	3.9	3.0	2.9	5.1	2.7
5	2.1	3.4	2.0	4.0	4.1	3.2
6	2.5	3.2	2.4	2.3	4.1	2.1
7	2.4	2.5	2.0	3.1	3.1	2.1
8	3.6	2.5	1.7	3.3		
9	5.1	3.3	2.6	4.8		
10	3.4	2.0	3.1	2.1	4.9	1.9
11	4.4	2.9	3.3	3.1	7.2	2.8

right lung became less efficient in each case (increased ventilation equivalent), but with the patient on the right side both sides showed a drop in the ventilation equivalent in several instances.

Vital Capacity.—Vital capacity determinations of each lung were secured in five patients. The results were inconstant. This may be due to technical factors as it is difficult for the patient to exert himself to the utmost when the catheter is in place. As can be seen from Table VII, there was a slight increase in several instances and some decrease in other readings when the patient was placed in one or the other lateral decubitus positions.

TABLE VII. VITAL CAPACITIES IN CUBIC CENTIMETERS AND PER CENT OF TOTAL

	SUPINE				RIGHT LATERAL				LEFT LATERAL			
	VOLUME		PER CENT		VOLUME		PER CENT		VOLUME		PER CENT	
CASE	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT
2	1970	1930	50	50	2116	2013	51	49				
3	1245	1598	44	56	1183	1702	41	59				
4	1532	1097	58	42	1349	1203	53	47	1681	1159	59	41
10	830	1930	30	70	809	2251	27	73	830	2033	29	71
11	1286	1556	46	54	1286	1571	45	55	1432	2691	35	65

DISCUSSION

Other authors have reported bronchospirometric studies with patients in the lateral decubitus position. We have been unable to find any articles in the English literature devoted to this subject. Pinner and associates,[4] in a general discussion of bronchospirometry, referred to studies of this nature made by Jacobaeus and by Vaccarezza and his colleagues, but we have been unable to secure these references. Frenckner and Björkman[5] in an article on the general subject of bronchospirometry make casual references to some work of this nature that they have performed but do not give any detailed figures. However, their findings and those quoted by Pinner were apparently similar to our own. An analysis of our results leads us to believe the following:

Total Oxygen Absorption.—The total oxygen absorption with the patient lying upon the right side is increased about one-third over the supine position. Almost all of this increase (an average of 95 per cent) is due to increased oxygen consumption by the right or under lung. When the patient is placed upon the left side there is about 10 per cent increase in the total oxygen absorbed, all due to an increase by the left lung. The difference in the increase between these two positions does not immediately lend itself to any obvious explanation. It might disappear in a larger series of cases. It is not apparent why the total oxygen absorption should increase with the patient in the lateral decubitus position. It is probably not due purely to nervous causes as the respiratory rate and depth of respiration showed very little change.

Differential Oxygen Absorption.—In each case the under lung showed a well-marked increase in the amount and percentage of oxygen absorbed. One suggested physiologic explanation for this finding is that the effect of gravity influences the normally low pulmonary arterial blood pressure resulting in a relative anemia of the upper and plethora of the under lung. The relatively

congested under lung presents a larger capillary bed for increased oxygen absorption. This increased efficiency is also reflected in the diminished ventilation equivalent.

Total Tidal Air.—This showed 4 per cent increase with the patient in the right lateral decubitus position and 10 per cent increase in the left lateral decubitus. These changes are probably within the range of experimental error.

Differential Tidal Air.—The differential tidal air in nearly every instance showed an increase in the percentage breathed by the under lung as compared with those proportions noted with the patient supine. It is difficult for us to understand why this should occur. In three of the cases there was paralysis of the diaphragm. Despite this fact the lung on the paralyzed side showed increased ventilation (as well as increased oxygen absorption) when the patient lay upon that side. The one patient who had artificial pneumothorax did not have readings made while lying on the pneumothorax side.

Ventilation Equivalent.—Changes in the ventilation equivalent are merely reflections of the changes in oxygen absorption and minute ventilation and need no further discussion.

As a clinical application of the findings described previously, we should like to note that on a number of occasions we have seen patients who were dyspneic due to unilateral pulmonary disease. In several instances such patients have preferred to lie on the uninvolved side and have found that the dyspnea vanished or was less distressing in this position. It is possible that this observation can be explained by the increased ventilation and increased oxygen absorption described here.

Vital Capacity.—The changes in the vital capacity were not constant.

SUMMARY

1. Bronchospirometry in the supine and right lateral decubitus positions has been performed in eleven patients. Six of these also had determinations made while lying in the left lateral decubitus position.

2. The total oxygen consumption increased an average of 34 per cent while lying on the right side and 9 per cent while lying upon the left. This was due almost entirely to an increase in the oxygen absorption by the under lung. In the majority a simultaneous decrease was noted in the oxygen absorption of the upper lung but in some this lung also showed increased oxygen absorption.

3. A definite increase in the percentage of oxygen consumption was noted in every instance in the under lung.

4. A slight increase in the total tidal air was noted in the lateral as compared with the supine position.

5. A slight but definite increase in the percentage of tidal air was noted in the under lung in the lateral position.

6. The ventilation equivalent, an index of respiratory efficiency, was decreased in the under lung, indicating increased efficiency.

7. The vital capacity showed inconstant changes.

CONCLUSIONS

Bronchospirometry done in the lateral decubitus position and compared with readings obtained with the patient in the supine position reveals a slightly increased percentage of ventilation and a moderate to marked increase in percentage of oxygen consumption in the under lung.

ADDENDUM

As a result of this study, an additional question was raised. Is the oxygen consumption increased in the lateral decubitus position in patients not undergoing bronchospirometry?

Ten patients were studied in the following manner: Oxygen consumption was determined in the supine, right lateral decubitus, and left lateral decubitus positions using the Benedict-Roth metabolism apparatus. These patients rested at least fifteen minutes prior to the determination, but were not in a basal state.

In each instance an increase in oxygen consumption was noted in the lateral decubitus position as compared with the supine position. The average O_2 consumption in the supine position was 306 c.c. O_2 per minute. While lying on the right side, the O_2 consumption increased to 386 c.c. per minute, an increase of 26 per cent. While lying on the left side, the O_2 consumption increased to 374 c.c. per minute, an increase of 22 per cent.

These findings are similar to those noted in patients undergoing bronchospirometry in the lateral decubitus position. The exact explanation for the increased utilization of oxygen with the patient in the decubitus position is not immediately apparent. A further study of his problem is being undertaken at this institution, and the results of this study will be reported at a later date.

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RESECTION OF AN INTRATHORACIC "HIBERNOMA"

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THE increasing application of thoracotomy in the diagnosis and treatment of intrathoracic lesions has stimulated new interest in benign tumors of the chest. Lipomas are among the less common, benign, intrathoracic neoplasms, approximately fifty-five cases having been reported.[1-14]

CASE REPORT

M. C. (No. 150-836), a 42-year-old housewife, was referred to the University of Kansas Medical Center July 1, 1948,* because roentgenologic studies had revealed the presence of a large mass in the left side of the chest. For five years she had noticed an intermittent, slightly productive cough during the winter months. In the six months prior to admission this symptom had become progressively severe and more productive. During this same period she had also experienced wheezing and it was because of this that she sought medical advice. She denied other cardiorespiratory complaints. The remainder of her medical anamnesis revealed nothing of significance.

The patient was an obese, middle-aged, white woman who did not appear ill. The inferior one-half of the left side of the chest presented limited respiratory excursions, dullness to percussion, decreased tactile fremitus, and absence of breath sounds. A complete physical examination revealed no further abnormal or pertinent findings.

Admission laboratory studies showed an initial red blood cell count of 5.13 million, a hemoglobin of 13.8 Gm. per cent, and a white blood cell count of 7,900 with 82 per cent polymorphonuclears. The urine was acid, with a specific gravity of 1.006, a faint trace of albumin, no sugar, and normal sediment. The Wassermann and Kahn blood reactions were negative. Blood nonprotein nitrogen was 37 mg. per cent, glucose 76 mg. per cent, and total protein 7.28 Gm. per cent, with an albumin fraction of 4.97 Gm. per cent and a globulin of 2.31 Gm. per cent.

An electrocardiogram evidenced minimal diffuse myocardial abnormality as shown by low T waves in the routine limb and in two precordial leads. Histoplasmin and tuberculin skin tests were positive. The complement fixation test for histoplasmosis was negative.

Lateral and posteroanterior roentgenograms of the chest demonstrated a huge homogeneous opacity, 17 by 13 cm., which nearly obscured the middle two-thirds of the left side of the chest. Posterolaterally, this density was continuous with the chest wall, while anteriorly, it presented a smoothly convex profile (Figs. 1 and 2). Special films did not reveal any roentgenologic evidence of alteration of the ribs or vertebrae.

Because of the composition, shape, and location of this density, the patient was thought most likely to have a tumor arising from an intercostal nerve.

Operation was performed July 3, 1948, under endotracheally administered cyclopropane-oxygen-ether anesthesia with the patient in the right lateral recumbent position. The left pleural space was entered through the bed of the subperiosteally resected seventh rib. At once a large, ovoid, firm, pink-yellow, bosselated tumor was apparent extending from the posterolateral chest wall to the mediastinum and from the diaphragm halfway to the apex (Fig. 3). A broad symphysis about 5 cm. in diameter attached the mass to the posterolateral chest wall. Vascularized adhesions bound the tumor to the upper and lower lobes of the

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Received for publication Aug. 18, 1949.

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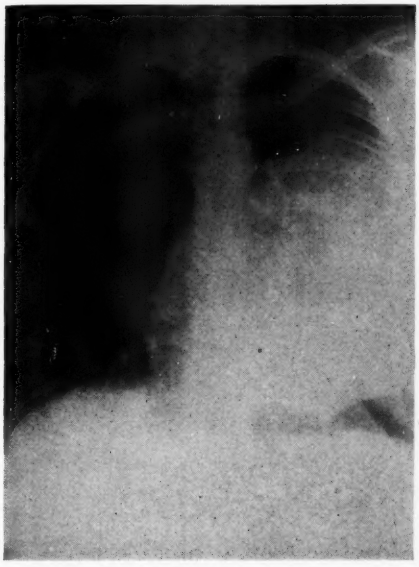

Fig. 1.

Fig. 2.

Fig. 1.—Roentgenogram demonstrating the large density filling almost the entire lower two-thirds of the left side of the chest.

Fig. 2.—Lateral film of the left side of the chest showing its posterior location, homogeneity, and smoothly convex border.

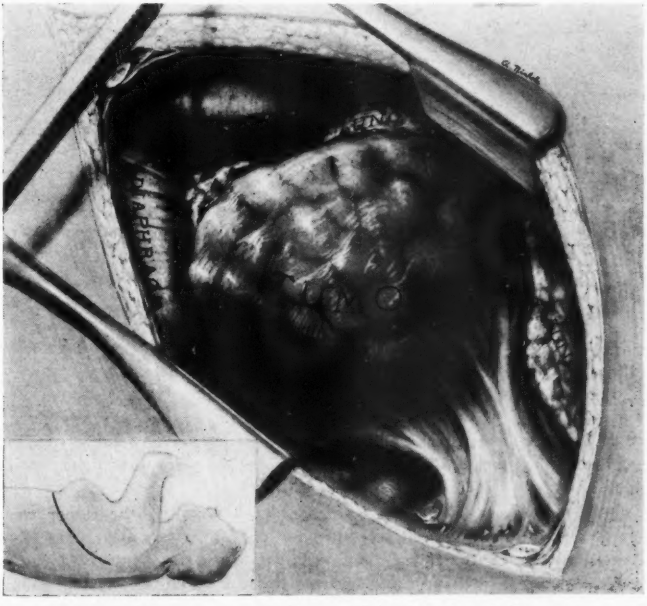

Fig. 3.—Sketch of the operative findings. Note the bosselation and ovoid shape of the tumor, its intimate adherence to the upper and lower lobes of the lung, and the broad symphysis attaching it to the posterolateral portion of the chest wall.

left lung. These were ligated and divided mobilizing the internal surface of the mass. To minimize the likelihood of recurrence the tumor was resected en bloc with the attached chest wall containing segments of the third, fourth, fifth, and sixth ribs.

The chest was closed by anatomic approximation of its layers. The thoracic cavity was not drained. The operative procedure required one hour and thirty-two minutes. Whole blood, 1,000 c.c., was administered intravenously.

The postoperative course was uneventful with the exception of 450 c.c. of a serosanguineous fluid which was removed by thoracentesis on the third postoperative day. The patient was discharged on the eleventh day following operation. She has been completely asymptomatic since.

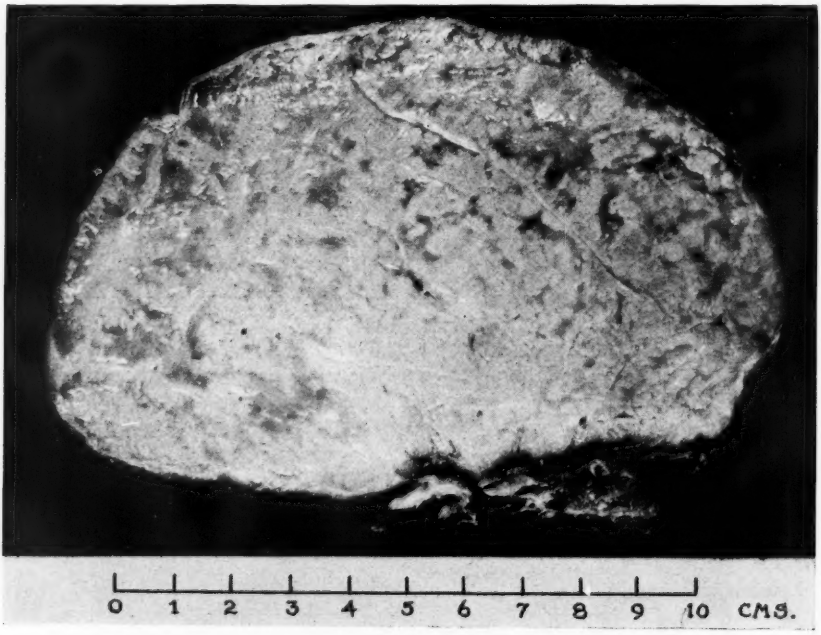

Fig. 4.—Cut surface of the tumor disclosing its glandular appearance. Observe the creamy gray substance interspersed by areas of translucent tissue. The symphysis attaching the tumor to the chest wall can be noted in the lower right-hand corner.

PATHOLOGIC REPORT

Gross Description (Fig. 4).—The specimen consisted of a large tumor mass attached to the pleural surface of a portion of chest wall containing segments of four ribs, each averaging 5 cm. in length, together with the intervening intercostal structures. The tumor was slightly bosselated, ovoid, pink, encapsulated, 14 by 12 by 8 cm., and weighed 1,000 Gm. Cut sections revealed a firm grayish-orange tissue interspersed by small, irregular, rather translucent, myxomatous areas. Thin-walled blood vessels were prominent on the surface of the tumor.

Microscopic Appearance (Fig. 5).—The capsule surrounding the tumor was composed of moderately dense fibrous tissue and was intimately attached to the parietal pleura.

The greater portion of the tumor tissue was comprised of clumps of large, ovoid cells, 15 to 60μ in diameter, separated into lobules by delicate trabeculate without definite pattern. The cytoplasm of the cells was eosinophilic and contained a varying number of large and

small vacuoles. In the larger cells, which were fewer in number, the cytoplasm was almost completely occupied by a single large vacuole. The nuclei were small, deeply chromatic, and usually centrally located except in the larger, unilocular cells where they were eccentrically placed.

In other parts of the tumor, which grossly appeared myxomatous, the cell walls had undergone dissolution leaving only scattered fusiform nuclei on a pale, fibrillary, basophilic background. Small groups of lymphocytes and plasma cells were present throughout the entire neoplasm, more predominantly in the degenerated areas.

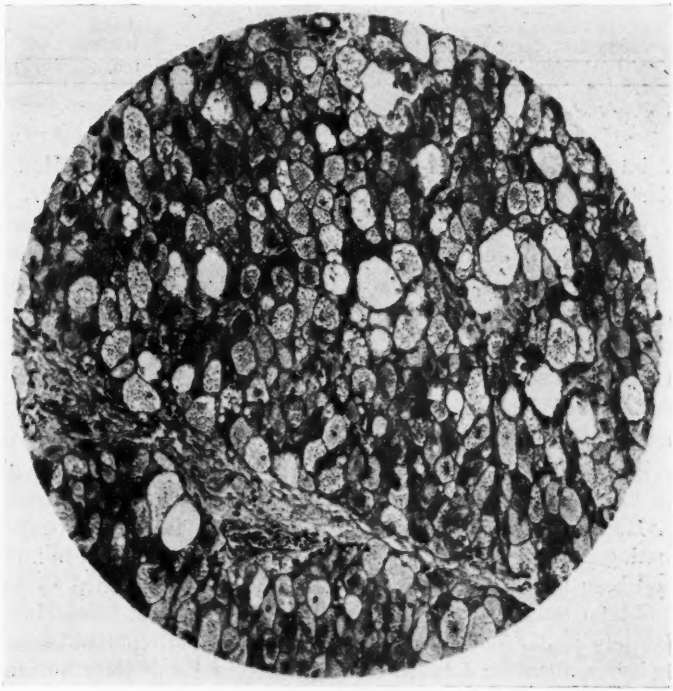

Fig. 5.—Photomicrograph illustrating the hibernoma cell type: ovoid and irregular, packed with fine and coarse cytoplasmic vacuoles, and possessing a small dark nucleus. Note the variations in vacuolar size and the resemblance of this tissue to immature fat.

Special stains revealed the cytoplasmic vacuoles to possess the tinctorial reactions of lipoid material.

Diagnosis.—Atypical lipoma derived from the human homologue of the hibernating gland (hibernoma).*

Chemical Analysis.—For comparison analysis† was done on a large subcutaneous lipoma simultaneously with the hibernoma. Findings were as shown in Table I.

The following tests were determined on the triglyceride of these tumors and are reported on that basis:

	LIPOMA	HIBERNOMA
Iodine number	50.9	55.0
Acid value	3.1	5.3
Melting point	22° C.	1° C.

*Dr. Brines confirmed this diagnosis and stated it to be identical with the neoplasm in his patient.[5, p.]

†This chemical analysis was done through the courtesy of Dr. E. L. Boley, Armour and Company, Chicago, Ill.

TABLE I

	LIPOMA (PER CENT)	HIBERNOMA (PER CENT)
Naturally occurring conjugated diene fatty acids	1.47	1.06
Naturally occurring conjugated triene fatty acids	0.01	0.01
Naturally occurring conjugated tetraene fatty acids	nil	nil
Linoleic fatty acids	2.04	4.62
Linolenic fatty acids	0.20	0.16
Arachidonic fatty acids	0.11	0.18
Total polyunsaturated fatty acids	3.83	6.03
Oleic fatty acids	50.38	51.06
Saturated fatty acids	45.79	42.91
	100.00	100.00

DISCUSSION

Most intrathoracic lipomas originate from the mediastinum. Hourglass or dumbbell shaped tumors, in their relation to the intercostal space, are less common while bronchial and parietally situated subpleural lipomas are rare.[3, 5, 17-21] With the increasing incidence of routine and survey chest roentgenograms, most of these tumors will be detected as asymptomatic opacities. Large lipomas will produce signs and symptoms according to their locations. Small tumors will command attention if endobronchially located.

The liability of sarcomatous change thus demanding immediate and complete surgical excision of lipomas has been stressed. [22,23]

Hibernoma, the particular type of tumor found in this patient, was probably first described by Merkel in 1905, with the term "adenoma of sebaceous gland."[24] The word hibernoma was introduced by Gery in 1914 while discussing a case report.[25] He believed it to be a neoplasm originating from homologues in man of hibernating glands. The specific form of adipose tissue present in hibernating glands had been known for many years, having been mentioned by Velsch in 1670,[26] and later studied by numerous authors.[27-29] Bonnot[30] and Hatai[31] used the name interscapular gland to depict this structure and reported its occurrence in human beings. From a detailed study of adult and embryonic human tissues, Bonnot traced its origin from the region of the primitive jugular vein. In man the interscapular gland is a paired, light brown, lobulated, irregular, vascular mass, situated on the shoulder and side of the neck between the superior borders of the scapula and clavicle. This glandular structure is composed of lobulated areas of multiloculated or coarsely granular fat cells occasionally surrounding small portions of lymphoid tissue, somewhat resembling the hemolymph glands of lower mammals. A variety of functions has been ascribed to this peculiar tissue: hemopoiesis, hemocatheresis, fat storage, an origin of the autonomic nervous system, part of the thymus, and as an endocrine gland.[27, 32]

Tumors of this structure have not been recognized except rarely. Brines and Johnson[16] presented the published cases, listing nine as reasonably authentic, seven possible, and describing one new instance. Although they do not approve of the nomenclature, they believe it to constitute a definite oncologic entity. It is probable that some of the neoplasms diagnosed as xantholipoma, myxolipoma,

pseudolipoma, lipoblastoma, atypical lipoma, and granular cell myoblastomas may be identical with the typical hibernoma.[16, 33, 34]

Positive identification of an intrathoracic lipoma can usually be accomplished only by exploratory thoracotomy or post mortem examination. Diagnostic needle biopsy of intrathoracic masses should not be employed as long as hope for curative therapy exists.

CONCLUSION

1. The successful resection of an unusual type lipoma, "hibernoma," occurring within the chest is recorded.

2. The importance of exploratory thoracotomy in the diagnosis of intrathoracic disease is emphasized.

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LATE RESULTS IN FOUR HUNDRED TWENTY TUBERCULOUS PATIENTS SUBJECTED TO THORACOPLASTY

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THE evaluation of the results of thoracoplastic treatment of pulmonary tuberculosis often causes difficulties. Nothing is gained from just stating the percentage of recovery of a small number of patients shortly after the operation. It requires a sufficient number of patients subjected to uniform methods of operation; exact information about this material must be at hand so that the condition of the patients immediately prior to operation is known, and so that it is evident what patients were selected for operation. Furthermore, it requires an observation period of at least two or three years, besides exact criteria, for the judgment of final results. Especially, it must be clear what is required for describing a patient as healthy, in which connection cultivation methods for tubercle bacilli from sputum and gastric lavage water must be considered. A systematic statement of results year by year after the operation would be still better.

The material stated in this paper meets these demands. It involves the total number of thoracoplasty patients in the Øresundshospital, Copenhagen, during the years 1935 to 1941. Altogether, the material comprises 424 patients with pulmonary tuberculosis subjected to paravertebral thoracoplasty on modern principles, including extensive resection of the upper ribs. However, operation in cases of empyema cavities, as well as other atypical operations, have been excluded. The subsequent investigation has given exact information about all the patients during at least three years after the operation: 141 have died, 132 of tuberculosis, 9 of another intercurrent disease, suicide, or the like. Of the latter, 4 died shortly after the operation, so that the permanent result could not be estimated. They have therefore been struck out of the material. The remaining 5 did not die until long after the operation, and as their condition immediately prior to death was known, they have been registered in accordance with their state of recovery in the period prior to death. Accordingly, the material thus corrected will include altogether 420 patients.

Table I shows the distribution according to sex and age. There is a slight preponderance of female patients. The majority of patients were between 20 and 40 years of age, only a very few above 50 and none below 15 years.

Table II shows the duration of the disease prior to operation. As it is impossible to establish the exact moment of onset of the disease, its inception is assumed to be the moment when tubercle bacilli were demonstrated for the first time in the respective patient. The majority of cases were chronic, with a case history of more than two years. Some patients, however, were operated on within six months. Still, that does not mean that fresh cases were submitted

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Received for publication Nov. 14, 1949.
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TABLE I. SEX AND AGE

AGE (YR.)	MALE	FEMALE	ALTOGETHER
Below 15	0	0	0
15 to 20	13	23	36
20 to 25	33	47	80
25 to 30	43	72	115
30 to 35	42	49	91
35 to 40	26	36	62
40 to 45	14	9	23
45 to 50	5	4	9
Above 50	1	3	4
Total	177	243	420

to operation, as part of these patients were actually chronic cases which were not disclosed and diagnosed until at an advanced stage of the disease. The general rule is that pneumothorax is first tried and, if that fails, the patient is confined to bed some months to see whether the processes present signs of regression under conservative treatment.

TABLE II. THE DURATION OF THE DISEASE FROM FIRST DEMONSTRATION OF TUBERCLE BACILLI TO OPERATION

More than 2 years	221
1 to 2 years	57
½ to 1 year	69
less than ½ year	73
Total	420

Previously applied active treatment is evident from Table III.

The status of the patients immediately prior to operation was as follows:

All were found to be bacillary, most of them by direct microscopy of sputum, a few by cultivation of sputum or of gastric lavage fluid.

Of the greatest importance are the roentgenologic conditions. First the operation side shall be discussed.

TABLE III. ANTECEDENT ACTIVE TREATMENT

	CASES
Pneumothorax impossible	198
Unsuccessful pneumothorax treatment	193
Pneumothorax treatment normally carried through before	29
Phrenic evulsion	15
Paraffin plombage	2
Unsuccessful attempt at extrapleural pneumothorax	5

TABLE IV. THE OPERATION SIDE

SITE OF THE CAVITIES	NUMBER	MULTIPLE CAVITIES	INVOLVEMENT OF MORE THAN ONE-HALF LUNG
Apical	78	7	28
Infraclavicular	218	30	141
Middle zone	67	19	55
Basal	2	0	2
Without cavities	55		37
Total	420	56	263

Thus, 87 per cent of the cases were cavernous, whereas cavities could not be demonstrated with certainty in 13 per cent (doubtful ring shadows and clearings of less than 1 cm. in diameter were omitted, and systematic tomography was not performed).

The cavities were divided into four groups:

1. Apical cavities, situated in a frontal picture on a horizontal plane through the first costal cartilage
2. Infraclavicular cavities, reaching further downwards, on a horizontal plane through the second costal cartilage
3. Middle zone cavities, at a lower level, on a horizontal plane separating the middle and lower one-third of the lung area
4. Basal cavities in the lower one-third of the lung area

The distribution is seen in Fig. 1.

Fifteen per cent had multiple cavities.

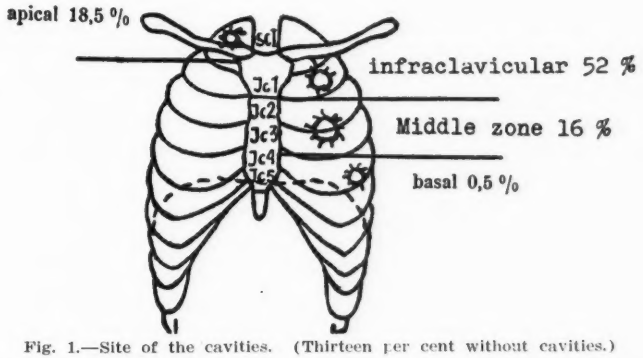

Fig. 1.—Site of the cavities. (Thirteen per cent without cavities.)

Table IV gives an idea of the degree of infiltration: the total affected area in no less than 63 per cent of the cases had an extent corresponding to more than one-half the area of the lung.

The size of the main cavity is seen in Table V. This added to earlier information shows that the material was heavily weighted.

TABLE V. THE SIZE OF THE CAVITIES

	CASES	PER CENT
Small, diameter less than 3 cm.	133	36
Large, diameter 3 to 6 cm.	179	49
Giant cavities, diameter more than 6 cm.	53	15

The next problem is the condition of the contralateral lung, which is seen in Tables VI and VII.

It appears that there was no hesitation in operating on patients with slight contralateral processes, whereas some reserve was shown when the latter extended over more than one-third of the area of the lung. In regard to activity it will be seen that the indications were fairly liberal; 20 per cent had doubtful and no less than 10 per cent clearly active processes.

TABLE VI. THE CONTRALATERAL LUNG: THE EXTENSION OF THE PROCESSES

	CASES	PER CENT
Sound lung	122	29
Infiltration less than one-half	258	61
Infiltration more than one-half	40	10
Total	420	

The total extension of processes in both lungs has been estimated according to Cold's division. There are four main groups:

1. All purely unilateral and all slight bilateral cases with affection of at most one-half of the cavernous side, affection of at most one-fourth or slight affection of at most one-half of the other lung
2. Moderate bilateral cases in which at most five-eighths of the total area of both lungs is affected
3. Bilateral cases with great extension
4. Bilateral cavernous cases

TABLE VII. THE CONTRALATERAL LUNG: THE ACTIVITY OF THE PROCESSES

			CASES	WITH PNEUMOTHORAX
Inactive	Sound lung	122	296	0
	Slight calcification	44		0
	Actual infiltration	130		1
Doubtfully active			84	9
Active	Without cavity	30	40	4
	With cavity	10		4
Total			420	18

The figures of Table VIII illustrate that a comparatively large number of heavily affected patients belong to this material.

Attention should not be focussed entirely on the roentgenologic conditions. Also, the clinical status of the patients, as to general condition, weight, temperature, etc., should be considered.

TABLE VIII. THE TOTAL EXTENSION OF THE PROCESSES

GROUP	CASES	PER CENT
1. Unilateral and slight bilateral	222	53
2. Moderate bilateral	162	39
3. Extensive bilateral	26	6
4. Bilateral cavernous	10	2
Total	420	

Attempt has been made to single out a particularly appropriate group of patients of good general condition with chronic fibrocavernous processes and slight contralateral affection. Such patients, who correspond to the ideal indications for thoracoplasty, are generally called good chronics.

The delimitation of such a group within the main body of patients, and the determination of its percentage within the total material afford a good survey of the extent of the indications. If the percentage is great, the surgeon has been very cautious; if it is small, the indications have been extended more

boldly. The definition of the notion "good chronics" varies somewhat in the reports of the different authors who apply it. In this material a good chronic means a patient who corresponds to the following criteria:

1. Normal temperature during the last two preoperative months
2. Stationary or increasing weight during the same period
3. No severe dyspnea or other more serious complications
4. Age between 15 and 50 years
5. Roentgenogram of lungs shows typical chronic process with retraction (possibly of unknown duration) or nontypical process, but unchanged picture during at least six months; processes involving less than one-third of the area of the contralateral lung, and inactive

TABLE IX. GOOD CHRONICS

	CASES	PER CENT
Good chronics	128	30
Remaining patients	292	
Total	420	

Table IX shows that only 30 per cent of the 420 patients were good chronics; thus, the indications have been very liberal.

The technical details of the operation itself will not be stated here; it is only emphasized that all cases deal with modern thoracoplastic operations involving extensive resection of the upper ribs.

In 261 out of the 420 cases apicolysis was performed in connection with the operation, so that the latter was carried out as a Semb apicolysis thoracoplasty.

TABLE X. THE OPERATION

RIBS	LESS THAN SIX	SIX TO EIGHT	MORE THAN EIGHT	ALTOGETHER
One stage	84	29	2	115
Two stages	12	213	17	242
Three stages	0	21	29	50
Four stages	0	4	9	13
Total	96	267	57	420

Further information is given in Table X, which also shows the extensive division of the operation into stages, although some of the minor apical thoracoplasties were performed in one stage.

Table XI shows the operation mortality (death within two months of the operation). It increases according to the extension of the tuberculous process.

TABLE XI. THE OPERATION MORTALITY

GROUP	NUMBER IN GROUP	OPERATION MORTALITY	
		NUMBER	PER CENT
1	222	15	7
2	162	14	9
3	26	3	12
4	10	4	40
Total	420	36	8.6

The permanent results of the operations can only be estimated on the basis of a long observation time. It is of no use merely to report—as is done by many authors—that the surgical treatment of cavernous phthisis has afforded this or that result on the patient's discharge from hospital. Despite well-being and apparent collapse of the lung many of these patients continue for a long time to discharge bacilli.

Therefore, the re-examinations of the patients in this study were carried through with an observation time of at least three years, even up to seven years, for the oldest patients. In spite of the difficulties of war all the patients could be traced and exact information about their condition could be obtained, so that the re-examinations could be terminated with a result of 100 per cent.

With regard to the permanent results the patients were divided into three groups: healthy, ill, and dead. To be characterized as healthy the patient must be:

1. Roentgenologically stationary, without signs of residual cavities; without signs of fresh processes or of progression
2. Abacillary, that is,
   (a) in case of expectoration, cultivation of the sputum must be without tubercle bacilli
   (b) if expectoration is impossible and gastric lavage has been performed, cultivation of the fluid must show no growth of tubercle bacilli
3. Without serious complications, such as severe dyspnea, persistent thorax fistulas, etc.

All the other surviving patients were called ill.

Thus, it is seen that cultivation for tubercle bacilli has been performed for all the patients with expectoration. In 75 per cent of the other cases gastric lavage was performed. Thus, it is evident that very rigorous conditions must be fulfilled before a patient is described as healthy, seeing that the mere growth of one colony of tubercle bacilli by cultivation of gastric lavage fluid makes that designation impossible.

TABLE XII. PERMANENT RESULTS OBTAINED IN THE TOTAL BODY OF PATIENTS

	NUMBER	PER CENT
Healthy	193	46.0
Ill	95	22.6
Dead	132	31.4
Total	420	

Of the surviving patients 67 per cent healthy
Operation mortality, 8.6 per cent

Table XII shows the permanent results obtained in the total material of patients. These results may not seem very brilliant, but it must be borne in mind that clinically as well as roentgenologically the material was heavily weighted, and all types of thoracoplasty were performed, from minor apical operations to the major total thoracoplasties comprising no less than 13 per cent of the operations.

TABLE XIII. PERMANENT RESULTS OBTAINED FOR THE GOOD CHRONICS

	NUMBER	PER CENT
Healthy	75	58.6
Ill	32	25.0
Dead	21	16.4
Total	128	

Of the surviving patients 70 per cent healthy
Operation mortality, 3.1 per cent

This is further illustrated in Table XIII. It appears that in the particularly appropriate cases the results are considerably better, with a recovery percentage of 58.6, and the operation mortality has decreased to 3.1 per cent. Besides, at the evaluation of results, it is important to emphasize the rigorous conditions required with regard to the demonstration of tubercle bacilli.

In most foreign materials direct microscopy for tubercle bacilli is the normal procedure, whereas cultivation methods are not used to a very large extent. Exact information about these facts is necessary for estimation of the final results of the operation.

From this material it appears that if cultivation from sputum and gastric lavage water is left out of consideration, 7 per cent more patients will be registered as abacillary, which means that the percentage of recovery will exceed fifty. Exact information about the total material as well as about the good chronics is given in Fig. 2.

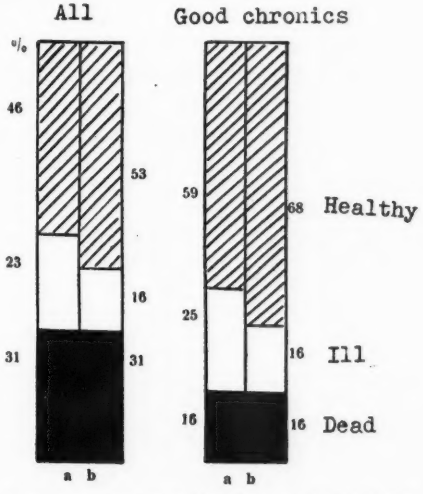

Fig. 2.—Late results: *a*, with cultivation methods; *b*, with only direct microscopy for tubercle bacilli.

The results are further illustrated in Tables XIV and XV, which show the importance of the cavity. It is remarkable that the results are very good for the middle-zone cavities, as well as for the large cavities with a diameter of more than 3 cm.

TABLE XIV. THE SITE OF THE CAVITIES

	APICAL	INFRACLAVICULAR	MIDDLE-ZONE	BASAL
Healthy	41 (53%)	93 (42%)	27 (41%)	1 (50%)
Ill	15	50	16	1
Dead	21	77	23	0
Total	77	220	66	2

TABLE XV. THE SIZE OF THE CAVITIES

	SMALL	LARGE	GIANT
Healthy	74 (56%)	77 (43%)	11 (21%)
Ill	23	43	16
Dead	36	59	26
Total	133	179	53

The importance of the contralateral lung is seen in Tables XVI and XVII. The best results are obtained when the contralateral lung is sound; however, even in cases of extension of the processes under one-third of the lung area the recovery percentage is good.

TABLE XVI. THE CONTRALATERAL LUNG: EXTENSION

	SOUND	LESS THAN ONE-THIRD	MORE THAN ONE-THIRD
Healthy	67 (55%)	115 (45%)	11 (28%)
Ill	24	64	7
Dead	31	79	22
Total	122	258	40

If the extension of the processes exceeds this limit, or if there are active processes in the contralateral lung, the chances of recovery diminish considerably.

TABLE XVII. THE CONTRALATERAL LUNG: ACTIVITY

	INACTIVE				
	SOUND	SLIGHT CALCIFICATIONS	ACTUAL INFILTRATIONS	DOUBTFUL	ACTIVE
Healthy	67 (55%)	25 (57%)	57 (44%)	38 (45%)	6 (15%)
Ill	24	10	37	17	7
Dead	31	9	36	29	27
Total	122	44	130	84	40

The total extension of processes is of great importance in the prognosis, as seen in Table XVIII.

It is remarkable that in Group 3 (extensive bilateral cases) a fairly great number of patients have recovered.

TABLE XVIII. THE EXTENSION OF THE PROCESSES

GROUP	1	2	3	4
Healthy	117 (53%)	68 (42%)	8 (31%)	0
Ill	48	41	5	1
Dead	57	53	13	9
Total	222	162	26	10

In Table XIX are seen the results of the different types of thoracoplasty, the material being divided according to the form of thoracoplasty planned for each individual patient: (1) apical thoracoplasty resection of up to five ribs; (2) upper lobe thoracoplasty, six to eight ribs; (3) subtotal and total thoracoplasty, above eight ribs.

TABLE XIX. RESULTS OF DIFFERENT OPERATION TYPES

THORACOPLASTY	TOTAL MATERIAL			GOOD CHRONICS		
	NUMBER	OPERATION MORTALITY (PER CENT)	HEALTHY (PER CENT)	NUMBER	OPERATION MORTALITY (PER CENT)	HEALTHY (PER CENT)
Apical	70	5.7	60	23	0	78
Upper lobe	281	8.9	45	89	3.4	57
Total	69	10.1	35	16	6.3	38
	420			128		

Real understanding of the results of thoracoplasty can only be gained through a comparison with the results obtained in corresponding cases through ordinary conservative treatment.

Such comparisons, however, require a material of conservatively treated patients corresponding to the existing thoracoplastic material.

A material of that description has already been published by Cold (of the Øresundshospital). His material comprises 695 patients with cavernous pulmonary tuberculosis, conservatively treated, and observed through a period of six years. A comparison between the thoracoplastic cases and Cold's older chronic cases shows, as illustrated in Table XX, that apart from some uncertain factors (different observation periods, etc.) the results for patients subjected to thoracoplasty are considerably better than for conservatively treated patients (46 per cent, as against 5.7 per cent).

TABLE XX. CONSERVATIVE AND THORACOPLASTIC TREATMENT

GROUP	NUMBER	HEALTHY (PER CENT)
1. Conservative	31	19
Thoracoplasty	222	53
2. Conservative	52	12
Thoracoplasty	162	42
3. Conservative	102	0
Thoracoplasty	26	31
4. Conservative	72	3
Thoracoplasty	10	0
Total Conservative	264	5.7
Thoracoplasty	420	46.0

This superiority on the part of thoracoplastic treatment applies to Groups 1, 2, and 3, as the graphic description of Fig. 3 will show.

Hardly any good results were registered for the bilateral cavernous cases, through either of the two treatments.

A still better basis of comparison is a group of patients collected by Cold and belonging to Groups 1 and 2, all of whom were fit for thoracoplasty.

TABLE XXI. GROUPS 1 AND 2

TREATMENT	NUMBER	HEALTHY (PER CENT)
Conservative	166	10
Thoracoplasty	251	51

A selection from the thoracoplastic material of all patients of the first five years in Groups 1 and 2, results in 251 cases, all of them with an observation period of five years. These two materials offer as great correspondence as is practically possible, and show a recovery of 51 per cent, as against 10 per cent in cases of conservative treatment.

TABLE XXII. GROUPS 3 AND 4

	THORACOPLASTY (FIVE YEARS)			CONSERVATIVE TREATMENT (SIX YEARS)
GROUP	3 (PER CENT)	4 (PER CENT)	3 AND 4 (PER CENT)	3 AND 4 (PER CENT)
Healthy	29	0	19	3
Ill	19	20	19	8
Dead	52	80	62	89
Number	21	10	31	396

Conditions regarding Groups 3 and 4 are illustrated in Table XXII. In bilateral cavernous cases results were very poor in both ways of treatment; thoracoplasty, however, may be tried in Group 3 as recovery was, after all, obtained in 29 per cent of the cases, whereas the chances of a conservative treatment are negligible.

Moreover, Cold has made up the results for good chronics, and as the definition of this category within the thoracoplastic material corresponds exactly to the definition used by Cold, the result is a material very suitable for comparison, consisting, as it does, of patients possessing the ideal indications for thoracoplasty.

TABLE XXIII. GOOD CHRONICS

	NUMBER	HEALTHY (PER CENT)
Conservative treatment	39	23
Thoracoplasty	76	62

Table XXIII shows that even if fairly good results are obtained by conservative treatment of this type of patients (23 per cent healthy) thoracoplasty is still very superior to it.

Thus, it follows that within a well-defined group of patients, corresponding to those generally subjected to thoracoplasty, the permanent results of thoracoplastic treatment are found to be far superior to those obtained by conservative treatment.

A fact of very great interest is the examination of the patient's history during the first years after the operation. Only through such an examination is it possible to gain real insight into the future fate of a patient.

Consequently, as sufficient information could be obtained about the patients all through the period of observation, the total material was made up year by year according to the principles earlier mentioned. Variations through the first five years are given in Fig. 4, corresponding variations for good chronics in Fig. 5.

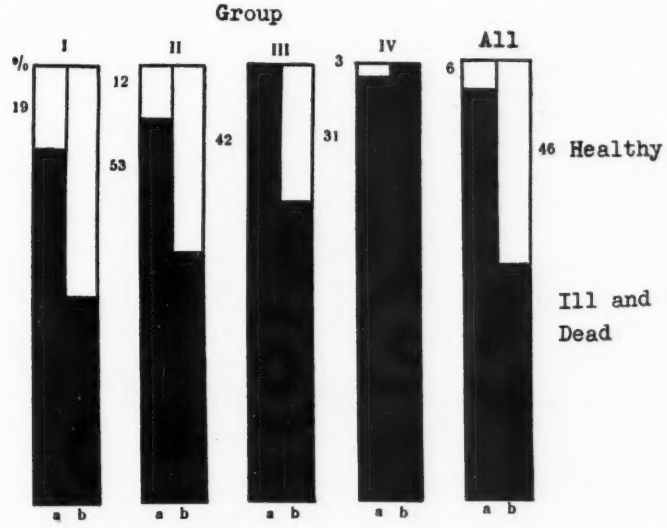

Fig. 3.—Conservative and thoracoplastic treatment. *a*, Conservative treatment; *b*, thoracoplasty.

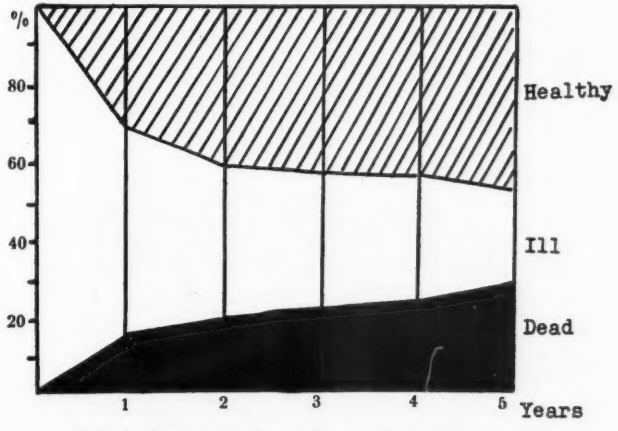

Fig. 4.—Thoracoplasty: 282 cases during five years.

The number of healthy patients shows a great increase during the first two years, after which it is fairly constant. Similarly, the mortality curve rises slightly during the first two years, and only a very little during the following years.

In other words, the permanent results of thoracoplasty cannot be evaluated until after an observation period of at least two years.

In the curve describing good chronics is seen the far greater percentage of recovery, as well as the very low mortality during the five years, within this group of patients.

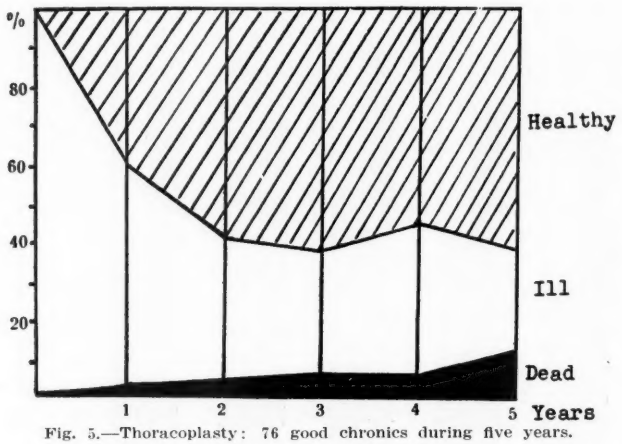

Fig. 5.—Thoracoplasty: 76 good chronics during five years.

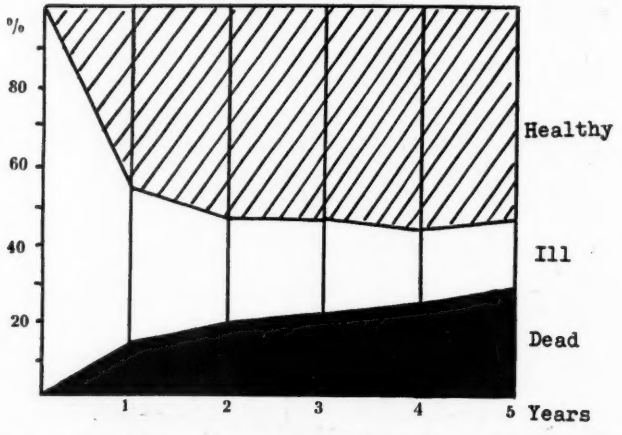

Fig. 6.—Thoracoplasty: 282 cases (without cultivation) during five years.

For comparison with materials in which only direct microscopy for tubercle bacilli is used, Figs. 6 and 7 illustrate the corresponding curves with results without cultivation methods. The results show up to still greater advantage, and already after one year the condition seems constant.

Finally, to point out once more the good results of thoracoplasty compared with those of conservative therapy, the history of Groups 1 and 2 are given through five years, as seen in Fig. 8 (without cultivation methods).

If this curve is compared with the corresponding curve of Cold's material (Fig. 9), it is impossible to overlook the striking superiority of thoracoplasty to the conservative treatment in similar cases.

It has often been argued that the effect of thoracoplasty is not so much a lowering of the death rate (at any rate not during the first four to six years), as an increase of the number of permanently abacillary patients, as well as

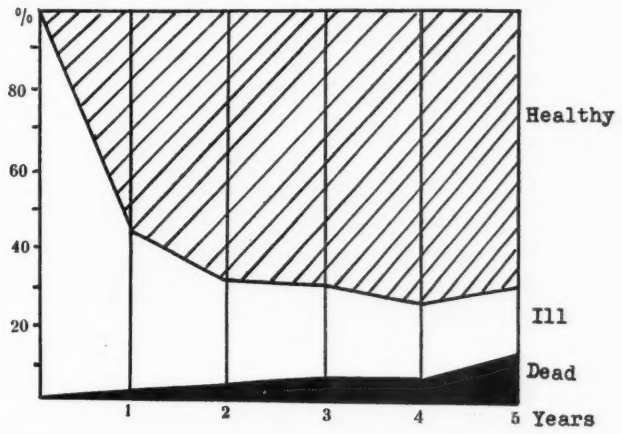

Fig. 7.—Thoracoplasty: 76 good chronics (without cultivation) during five years.

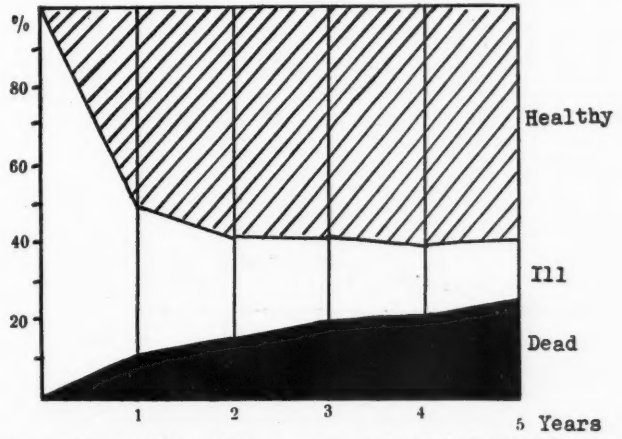

Fig. 8.—Thoracoplasty: 251 cases, Groups 1 and 2, during five years.

quickened debacillation. The curves of this material certainly indicate quicker debacillation, but at the same time the mortality of thoracoplastic cases (Fig. 8) is considerably lower than that of conservative treatment (Fig. 9).

The same thing applies to the good chronics, whose mortality curves are recorded in Fig. 10.

Thus, it must be admitted that modern thoracoplasty decreases mortality to a large extent compared with conservative methods, at any rate during the first five years after operation.

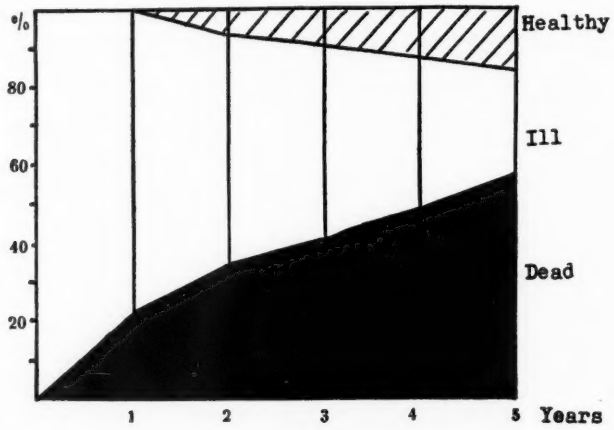

Fig. 9.—Conservative treatment: 90 cases, Groups 1 and 2, during five years.

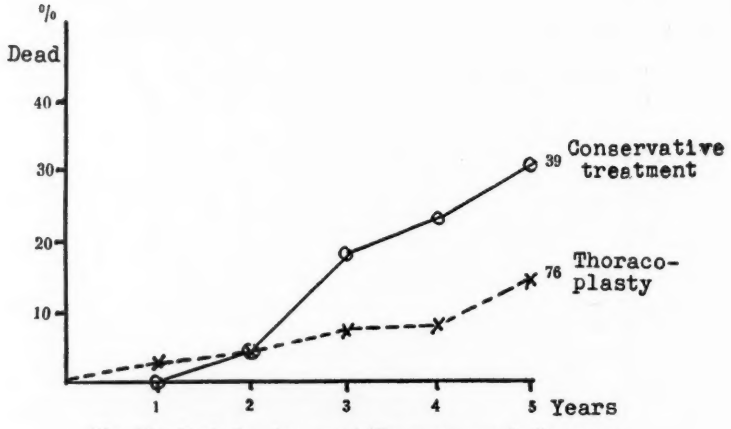

Fig. 10.—Good chronics: mortality curve, one to five years.

It should be remembered, too, that the description of a patient as "ill" does not imply that he is completely an invalid. Part of the patients had a large cavity and plenty of sputum before the operation, and their condition was unstable. The operation caused considerable improvement of the general condition, involving apparent collapse of the cavity, decrease of sputum, etc., the patient feeling well and fit for work; however, examination with cultivation from sputum and gastric lavage water revealed occasional growth of bacilli. Thus, it may be stated from the thoracoplastic material that after five years 63

patients were ill. Twenty-seven per cent of these were in good general condition and a roentgenologic examination showed apparently good collapse; no residuary cavities could be demonstrated with the methods used, and the x-ray picture remained stationary.

However, in 10 patients, examination of sputum showed plus tubercle bacilli directly, and, in 8, plus tubercle bacilli on cultivation. The remaining 9 showed plus tubercle bacilli on cultivation from gastric lavage water. In some cases cultivation showed growth of only one, or a few, tubercle bacilli colonies; thus, after all, thoracoplasty caused a not inconsiderable improvement of the general condition. Further research will show the prognosis of such cases.

DISCUSSION

Compared with cases of conservative treatment, this survey has shown fairly good results of the thoracoplastic treatment of chronic cavernous phthisis.

If the operation material is selected from the group of good chronics, excellent results are obtained for all forms of thoracoplasty, namely, recovery of rather more than 60 per cent, as against 20 to 25 per cent by conservative treatment. Further, the operation mortality is very low, about 3 per cent. Thus, within this field thoracoplasty must no doubt be considered the fundamental therapy, and preferable to conservative treatment. On the other hand, the question of the value of thoracoplasty compared with other methods, for example, extrapleural pneumothorax, has not been dealt with in the present work.

Extension of thoracoplasty indications beyond these limits—so that patients with poorer general condition and major contralateral processes are included—will, of course, lower the percentage of recovery. Examinations have shown that even in case of inactive affections in the contralateral lung of up to one-third of the lung area, the results obtained are far better than corresponding results of conservative treatment; in fact, even for doubtfully active processes in the contralateral lung, possibly with pneumothorax, fairly good results are obtained. Similarly, examinations regarding the size of the cavity on the operation side show that good results are obtained even for cavities with a diameter of up to 6 cm. These cases which, with regard to the total extension of the processes, belong to Groups 1 and 2, show a recovery percentage of about 50 and an operation mortality of 6 or 7 per cent, that is, far better than by conservative treatment, which can boast only about 10 per cent healthy patients in corresponding cases. Thus, a considerable extension of thoracoplasty indications beyond the good chronics is fully justified.

The point, then, is where to draw the limit, or, in other words, does thoracoplasty pay in cases of heavy bilateral extension or of bilateral cavernous affection? As mentioned previously, practically no good results are obtained in these groups by conservative treatment. In cases of bilateral cavity, thoracoplasty does not, either, show any good results, even if the material contains few cases of this category, and probably should not, as a rule, be applied to such patients. On the other hand, thoracoplasty of advanced cases without contra-

lateral cavity has, after all, yielded good results; as mentioned, out of 21 patients, 25 per cent were healthy after five years, and the operation mortality was only 5 per cent. This means that thoracoplasty may afford some chance of recovery if special indications speak in favor of it, for example, if the patient insists on active measures because he is heavily affected mentally at the prospect of a prolonged and hopeless conservative treatment.

The summing-up of the thoracoplastic material, moreover, shows that the good results are obtained at an early stage, appearing as they do, within the first two years after the operation, after which time the condition remains fairly constant, that is, quick debacillation and permanent increase of the number of abacillary patients. Thus, modern thoracoplasty of chronic cavernous phthisis has shown its superiority to conservative therapy, even in case of widely extended indications, and should occupy a dominating position within the treatment of these forms of tuberculosis.

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AN EVALUATION OF APICOLYSIS IN THORACOPLASTY

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DURING the technical development in recent years of thoracoplastic operations for the treatment of pulmonary tuberculosis, the ideal kept in view all along has been adhesionless pneumothorax with its concentric retraction of the lung in all three planes. Through modern selective thoracoplasties involving radical resection of the upper ribs, it is possible to obtain intensive collapse of the upper parts of the lung from side to side and also, to some extent, from front to back. In a great many cases this will be sufficient for a possible cavity to collapse completely; however, in some cases where the apex of the lung adheres upward medially toward the mediastinum, the roentgenogram will sometimes reveal an oblong, vertical residuary cavity. This absence of collapse in apicocaudal direction has led to attempts at combining thoracoplasty with extrapleural loosening of the lung apex so as to bring about retraction in all three directions.

These attempts have led to such operations as paraffin plombage and extrapleural pneumothorax, but also in connection with thoracoplasty apicolysis has earlier been used with little success. Semb, with his extrafascial apicolysis thoracoplasty, was the first to create a really radical and permanent apicolysis. This is the principle of his method: (1) radical and selective apicolysis performed through open dissection in the extrafascial layer; (2) radical rib resection, the extent of which corresponds to the apicolysis or more than that, so as not to leave behind any fragments of ribs that might "draw out" the lung again; (3) mobilization of rib periosteum following the surface of the lung, so that regeneration of the ribs will take place immediately over the loosened, collapsed part of the lung apex. This prevents re-expansion of the lung as well as of lung hernias.

Experience from literature on the subject yields little information as to indications for apicolysis. The use of the method seems to be a matter of routine, at any rate in operations in the upper lung regions. Results seem to be fairly satisfactory, though no reliable basis of comparison with nonapicolysis cases is at hand. It should, in this connection, be remembered that thoracoplastic technique has developed so rapidly in recent years that it has been impossible to form a lasting impression of an operation method until the next was introduced. Evaluation of these methods requires an observation time of at least two or three years after the operation, and if at the same time a comprehensive material is to be provided, it will take some years to collect this material, especially if it must be done in the same hospital.

Attention should therefore be directed to that development of thoracoplasty, including division of the operation into several stages and radical resec-

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Received for publication Nov. 14, 1949.

tion of the upper ribs, which took place immediately before, or simultaneously with, the first appearance of apicolysis. The improvement of results appearing from articles on the subject, may be due to these circumstances as well as to apicolysis, and it is hard to decide which of these is more responsible for it. It should not be left unnoticed that operators who do not make use of apicolysis, in many cases obtain results equal to those of Semb.

It is evident from this that the value of apicolysis has not yet been established, owing to the absence of a material suitable for thorough comparison. In the following, attempt is made to provide such a material from among the thoracoplasty patients of the Øresundshospital during the years 1935 to 1941. Here, K. Tørning, as one of the first operators outside Norway, has subjected this method to examination. At first apicolysis was used only as an experiment, and then only in case of apical medial cavities; later on, however, it was used more extensively. All through this period, in which, incidentally, the operative technique used was on the whole the same, there was a suitable number of operations with, as well as without, apicolysis. As early as 1940, Tørning expressed some scepticism toward the use of apicolysis in ordinary upper-lobe thoracoplasty, whereas he did not question its value in apical operations.

The material to be used for a comparative investigation was described in detail in the preceding article, "Late Results in 420 Tuberculous Patients Subjected to Thoracoplasty,"* and the patients of the years 1935 to 1939 comprise altogether 282 nonselective cases of lung tuberculosis treated with thoracoplasty. The material is evenly distributed, apicolysis being performed in connection with thoracoplasty in 148 cases, while the remaining 134 patients were not submitted to apicolysis. The results of these thoracoplasties were divided according to the principles mentioned earlier into three categories: healthy, ill, and dead. The same observation period, five years after operation, applies to all cases. This should provide a good basis for examining the value of apicolysis.

Table I gives a statement of the total material after an observation period of five years.

TABLE I. PERMANENT RESULTS AFTER FIVE YEARS

	134 WITHOUT APICOLYSIS		148 WITH APICOLYSIS	
	NUMBER	PER CENT	NUMBER	PER CENT
Healthy	63	47.0	71	48.0
Ill	29	21.6	34	23.0
Dead	42	31.4	43	29.0
Operation mortality	11	8.2	11	7.4

It appears from this statement that the figures of the two groups correspond exactly to one another, which means that at any rate in the total material apicolysis does not seem to have carried any effect in one direction or the other. However, the statement does not necessarily signify that apicolysis is of no value at all. In a limited number of cases it may very well have a certain favorable effect, which, on the other hand, is too slight to affect the total material. Besides, various factors may intervene, as in cases when the

*See page 837 for article.

two groups are, perhaps, not after all quite comparable with each other; thus the apicolysis group might contain some more poor objects of operation, who lower the recovery percentage as much as apicolysis might increase it. Apart from the fact that examination of the material reveals no sign of abnormal distribution, a somewhat closer analysis of results will be necessary.

In order to obtain two uniform groups of patients it would be practical to select the good chronics mentioned in the preceding article,* who fulfill the ideal indications for thoracoplasty. Such a selection would eliminate all poor objects of operation, who might otherwise be unevenly distributed, and provide two easily comparable groups. Examination of the material according to the previously mentioned criteria for the designation of good chronics shows that there are altogether 76 cases of that description. Table II shows the results of the two groups: 31 without and 45 with apicolysis.

TABLE II. SEVENTY-SIX GOOD CHRONICS

	WITHOUT APICOLYSIS	WITH APICOLYSIS
Healthy	20 (64.5%)	27 (60.0%)
Ill	7	11
Dead	4	7
Total	31	45

This statement, too, does not show any deviations in favor of the use of apicolysis.

However, further elucidation of the question is possible through division of the material according to the extension of the lung processes, as they appear on the roentgenogram. The following table shows the results of the different groups with and without apicolysis.

TABLE III. EXTENSION OF PROCESSES

GROUP		WITHOUT APICOLYSIS	WITH APICOLYSIS
1	Healthy	32 (53%)	47 (58%)
	Ill	14	18
	Dead	14	16
2	Healthy	27 (48%)	22 (42%)
	Ill	13	13
	Dead	17	18
3	Healthy	4 (33%)	2 (22%)
	Ill	2	2
	Dead	6	5
4	Healthy	0	0
	Ill	0	1
	Dead	5	4

Comparison shows that only in Group 1, the mildest cases, the percentage of "healthy" patients treated with apicolysis is slightly higher than that of the nonapicolysis group. This difference, however, is negligible, and also in the other groups with larger extensions of the processes apicolysis has had no favorable effect.

On the other hand, great importance must be attached not only to the extension of processes, but also to the site of possible cavities; and so it will be

*See page 837 for article.

useful to examine this circumstance in order to find out, if possible, whether in cases of uniform extension apicolysis has proved valuable to any particular group of patients.

For that purpose analysis was made with a view to the site of the cavity, and to the results of groups with and without apicolysis. It appears that the present material contains altogether 239 undoubtedly cavernous cases. Division according to the site of the cavity was made into the four groups mentioned earlier, namely, apical, infraclavicular, middle-zone, and basal cavities; in case of multiple cavities only the largest was considered. The distribution shows 54 cases of apical cavity, 137 of infraclavicular, 46 of middle-zone, and only 2 cases of basal cavity. Disregarding the 2 cases of basal cavity, the results of the different groups are stated in Table IV.

TABLE IV. SITE OF THE CAVITY

	APICAL		INFRACLAVICULAR		MIDDLE-ZONE	
	WITHOUT APICOLYSIS	WITH APICOLYSIS	WITHOUT APICOLYSIS	WITH APICOLYSIS	WITHOUT APICOLYSIS	WITH APICOLYSIS
Healthy	5 (36%)	18 (45%)	31 (47%)	33 (47%)	15 (50%)	7 (44%)
Ill	4	14	12	13	6	4
Dead	5	8	23	25	9	5
Total	14	40	66	71	30	16
	54		137		46	

Examination of these figures shows no effect of apicolysis when applied to middle-zone and infraclavicular cavities; in the group of apical cavities, however, the number of healthy patients is slightly greater among apicolysis cases, though the difference is not significant. A combination of this division with a division according to the extension of processes, as shown in Tables V and VI, yields the same result for infraclavicular and middle-zone cavities; in groups of uniform extension and the same cavity position there is no sign that apicolysis is effective. On the other hand, with regard to apical cavities Group 1 shows a higher percentage of recovery for apicolysis cases, namely, 73 per cent healthy as against 20 per cent in the nonapicolysis group. The figures of the latter group, however, are so low that care should be taken not to draw too far-reaching conclusions. Besides, some remarks must be added to the analysis stated. In the first place, in cases of multiple cavities only the largest cavities were taken into consideration. This might affect the result, as there are some cases of cavities scattered over a large part of the lung area. Accordingly, it was

TABLE V. EXTENSION AND CAVITY POSITION

	INFRACLAVICULAR		MIDDLE-ZONE	
GROUP	66 WITHOUT APICOLYSIS (PER CENT HEALTHY)	71 WITH APICOLYSIS (PER CENT HEALTHY)	30 WITHOUT APICOLYSIS (PER CENT HEALTHY)	16 WITH APICOLYSIS (PER CENT HEALTHY)
1	64	61	50	50
2	38	38	62	45
3	33	22	33	0
4	0	0	0	0

attempted to single out such cases and eliminate all patients with multiple cavities if these were situated outside the field of the largest cavity. For this reason, altogether 22 cases had to be left out of consideration. The corrected figures, however, show a percentile accordance with the figures of the tables quoted, so that this circumstance does not affect the results.

Next it should be mentioned that in grouping the cavities, one extending over several of the lung fields mentioned is here described as belonging to the lowest field it touches, that is, that a cavity described as infraclavicular may very well extend into the apex area, but not into the middle-zone area; on the other hand, an apical cavity is situated exclusively in the apex. In other words, besides the apical cavities discussed previously, there is an additional number touching the apex. In this material there are, besides the 54 purely apical cavities, 39 infraclavicular cavities extending into the apex, and, finally, to these may be added 3 cases of large cavities extending from the middle zone right into the apex. An illustration of this is given in Table VII. It appears that there is only a slight difference in favor of cases treated with apicolysis. Correction with regard to multiple cavities does not alter the picture.

TABLE VI. APICAL CAVITIES

	WITHOUT APICOLYSIS		WITH APICOLYSIS	
GROUP	NUMBER	HEALTHY (PER CENT)	NUMBER	HEALTHY (PER CENT)
1	5	20	29	73
2	8	50	10	30
3	0	0	0	0
4	1	0	1	0

In order to see clearly the effect of apicolysis in apical cases it might, besides, be useful to examine the cases which only showed apical cavities and, as before, distinguish between medial and lateral cavities. This is shown in Table VIII, in which are stated the 54 cases of apical cavities; however, cases of multiple cavities all through the area were not considered; thus, only 43 cases of solitary cavities were registered. Distinction was made between medial cavities whose medial edges reach as far as, or into, the processus transversus area, and the remaining lateral cavities.

TABLE VII. CASES OF CAVITIES TOUCHING THE APEX

	WITHOUT APICOLYSIS	WITH APICOLYSIS
Healthy	9 (33%)	29 (42%)
Ill	7	19
Dead	11	21
Total	27	69

No great effect seems traceable from the use of apicolysis either with regard to medial or to lateral cavities.

Accordingly, this examination of the importance of apicolysis in proportion to the extension of processes and the site of cavities reveals that in the more severe cases of infraclavicular and middle-zone cavities which comprise the

majority of cases, apicolysis seems to have had no effect. However, in cases of slight extension and apical cavity it cannot be precluded that apicolysis may have a certain profitable effect.

These questions may also be regarded under a different angle, if the problem is analyzed with a view to the extent of the thoracoplastic operation. In planning this, attention was paid not only to the size and site of the cavity, but the extension of the total process was estimated before decision was taken

TABLE VIII. CASES OF APICAL CAVITIES

	MEDIAL CAVITY		LATERAL CAVITY	
	WITHOUT APICOLYSIS	WITH APICOLYSIS	WITHOUT APICOLYSIS	WITH APICOLYSIS
Healthy	2 (50%)	5 (50%)	3 (43%)	10 (46%)
Ill	1	1	2	8
Dead	1	4	2	4
Total	4	10	7	22
	14		29	

as to how many ribs should be resected. Below, the material is divided, according to the extent of the operation, into the three main groups earlier mentioned: apical thoracoplasty (up to 5 ribs), upper-lobe thoracoplasty (6 to 8 ribs), and subtotal and total thoracoplasties (more than 8 ribs). Next, correction has been made for unsuccessful and incomplete thoracoplasties, as otherwise a number of large operations which could, for several reasons, not be completed, would be described as unsuccessful apical thoracoplasties. Altogether these cases total 55 apical, 185 upper-lobe, and 42 total or subtotal thoracoplasties, and the results of the various groups with and without apicolysis are stated in Table IX.

TABLE IX. SIZE OF THE OPERATION

	APICAL THORACOPLASTY		UPPER-LOBE THORACOPLASTY		TOTAL THORACOPLASTY	
	WITHOUT APICOLYSIS	WITH APICOLYSIS	WITHOUT APICOLYSIS	WITH APICOLYSIS	WITHOUT APICOLYSIS	WITH APICOLYSIS
Healthy	7 (41%)	26 (68%)	41 (47%)	41 (42%)	15 (52%)	4 (32%)
Ill	5	8	19	22	5	4
Dead	5	4	28	34	9	5
Total	17	38	88	97	29	13
	55		185		42	

Examination of these figures shows, on the whole, a repetition of the circumstances applying to cavity position, as after all was to be expected. Apical operations show a somewhat higher percentage of recovery in the apicolysis group, yet the difference is not significant. A division into uniform groups with regard to the extension of processes according to Cold shows similar conditions in Group 1, to which the majority of cases belong. On the other hand, no advantage seems to arise from the use of apicolysis in case of major operations (upper lobe and total thoracoplasty). In this connection it must be remembered, however, that the apicolysis group contains more severe cases than the nonapicolysis group, the latter containing a number of cases with fairly limited

middle-zone or basal processes in which the apex is not affected and in which, therefore, apicolysis has not been used. The apicolysis cases, on the other hand, usually show processes stretching right from the apex down through the lung area. If correction is tried in these cases it appears that there is no change in favor of apicolysis; however, the figures are fairly small. Thus, the statement shows that only with regard to purely apical operations is there, perhaps, some possibility of effect through the use of apicolysis.

Finally, it may be added that examination of the importance of dividing the operation into several stages shows no indication that apicolysis should have a favorable effect within groups of uniform types of operation performed partly in one, partly in several stages, except in the group comprising apical thoracoplasties performed in one stage. Here the percentage of recovery is higher in apicolysis cases, which is in accordance with the earlier results.

Accordingly, the total result of these examinations shows that the use of apicolysis as a part of thoracoplastic operations has proved unable to affect the permanent results of the total material, and with regard to infraclavicular and lower processes, that is, upper-lobe and total thoracoplasties, which include three-fourths of the operations performed, a closer analysis shows that no effect of apicolysis was traceable. In case of purely apical processes some favorable effect of apicolysis could not with certainty be precluded in the material at hand.

SIZE OF THE APICOLYSIS

After these reflections, which largely reduce the use of apicolysis, the question presents itself whether the apicolyses performed in this material were radical enough. Accordingly the 148 apicolysis cases have been examined with the object of ascertaining the extent to which the lung was loosened. Through the apicolysis the lung, as is known, sinks to at least the level of the fourth rib at the back, and the apex is seen lying free 6 or 8 cm. below the bundle of nerves and vessels. Analysis of the material shows that the loosening of the apex was now and then impeded by extensive adhesions; occasionally reserve was shown for fear of cavity rupture. Therefore, in some cases the apicolysis was not completed, only a partial apicolysis being performed, and, in consequence, distinction has been made between these minor apicolyses and more extensive loosenings. Among the former are classed apicolyses in which the loosening does not extend lower than the third rib, whereas the major loosenings all extend to the fourth or even lower ribs.

It appears that most of the apicolyses were satisfactorily performed, 123 out of 148 being major apicolyses (83 per cent)—of these no less than 60 per cent as far as about the fifth rib, or lower. The remaining 25 were minor or partial apicolyses.

It might be conceivable that the patients subjected to minor apicolyses fared worse than the rest. However, Table X, in which the results of these groups after five years are stated, shows that this is not so.

After these statements the question might be asked whether a number of drawbacks cling to the use of apicolysis in connection with thoracoplasty, even

TABLE X. SIZE OF THE APICOLYSIS

	MINOR APICOLYSIS	MAJOR APICOLYSIS
Healthy	15 (60%)	56 (46%)
Ill	4	30
Dead	6	37
Total	25	123

if the final results of the groups with, and without, apicolysis show little difference; or, in other words, whether the procedure in question may be the cause of more, or of additional and more serious, operative complications than is the case without the use of apicolysis.

As it is here a question not of late results, but only of the unfavorable complications following immediately upon operation, attempts have been made to ensure as comprehensive a material as possible by basing the examination not only on the patients observed through five years, but on the total material. Altogether there are 420, of whom 261 were subjected to operation with apicolysis, and 159 to operation without apicolysis.

INFECTION IN THE WOUND CAVITY

Examination of the material shows that 75 out of 420, that is, 18 per cent, had postoperative wound infection. As for degree and description of the infection, distinction was made between two groups.

The first group contains cases of slight infection, involving inflammation of the skin, the subcutaneous tissue or the superficial muscles; as a rule there was a subcutaneous undermining, often with fistula formation resulting in purulent secretion, generally of short duration; in a number of cases, however, these fistulas would persist for several months. In cases where the secretion was subjected to a bacteriologic examination it was, as a rule, a matter of ordinary pyogenic bacteria, and in a very few cases, of tuberculous infection. The second group contains more serious cases involving deeper infections in the subscapular cavity with fistula formations which, unlike those of the former group, were mostly very resistant to therapy and often kept on persistently in spite of excisions, lavages, or other operations. In some cases they involved invalidity and had existed for several years. Tuberculous infection occurred in 5 cases, while the remaining cases were due to ordinary pyogenic infection.

Distribution with regard to apicolysis is shown in Table XI.

It appears that the infection percentage was somewhat higher in the apicolysis group, and, more important, that while the slight wound compli-

TABLE XI. WOUND INFECTION

	WITHOUT APICOLYSIS (169)		WITH APICOLYSIS (261)	
INFECTION	NUMBER	PER CENT	NUMBER	PER CENT
In chest wall	25	16	41	16
Subscapular	0		9	3
Total	25	16	50	19

cations in the chest wall occur with the same degree of frequency in the two groups, the difference was due to the more serious, and intractable, subscapular fistulas occurring only in the apicolysis group. It is thus to be feared that apicolysis involves a greater risk of troublesome wound infections. Here it must be borne in mind that the material dates from the time before penicillin and streptomycin came into use in connection with thoracoplasty.

AFFECTION OF THE VASCULAR SYSTEM

Affection of the vascular system involving lower blood pressure and shocklike conditions is of frequent occurrence in thoracoplastic operations. Already during the resection of the first rib, as well as during the apicolysis itself, a lowering of the blood pressure is often noticeable, sometimes transient, but also passing into a surgical shock proper, developing in connection with, or subsequent to, the operation. Unfortunately in the present hospital there have been no examinations of this circumstance, such as determining hemoconcentration, or the like; thus, the only means at hand to diagnose the shock have been the blood pressure, the pulse rate, and the clinical estimate. Accordingly it has also been impossible to ascertain whether this lowering of the blood pressure is at all connected, pathogenically, with actual shock.

In order to overcome these difficulties it was decided, with a view to ascertaining the affection of the vascular system, to examine the circumstances of the blood pressure, as done by Semb in his material, in which the dividing line is drawn at a systolic blood pressure of 85 mm. Hg. It then appeared that a drop below this line occurred in 41 cases without apicolysis, that is, 26 per cent. In the apicolysis cases the drop occurred 54 times, or 21 per cent. Thus, apicolysis has not increased the number of such cases, the less serious of which are, as a rule, controlled by placing the patient's head in a low position and administering ephedrine injections, whereas in all shocklike conditions blood transfusion is the sovereign remedy.

OTHER COMPLICATIONS

Other important complications are postoperative pneumonias. As especially Semb has demonstrated, the development in this respect is an increase of bronchial secretion after the operation and, as a consequence of poor expectoration, the formation of atelectasis and subsequent infection and pneumonia. In other cases secretion may obstruct the bronchi, thereby involving danger of choking. A number of deaths are, no doubt, due to such conditions and not, as generally stated, to weakening of the heart. On the whole, heart complications are rare and not very important in local thoracoplasties. Cases of highly increased bronchial secretion and threatened choking were observed in 6 nonapicolysis cases and in 9 cases treated with apicolysis. In several of these cases bronchoscopy was performed and the secretion was aspirated. Pneumonia was observed in 6 nonapicolysis cases and in 8 apicolysis patients. Thus, the two groups present no very great variation in these respects.

Other complications, which occurred only in a limited number of cases, were, for example, lesions of nerves, vessels, pleural ruptures, cavity ruptures,

emboli in the pulmonary artery, besides other and more incidental complications. Such cases are found scattered throughout the material in the group with, as well as in the one without, apicolysis. It should be mentioned, however, that Horner's syndrome with miosis, ptosis, and enophthalmus besides, sometimes, absence of sweating in the affected side of the face, occurred in 7 patients subjected to apicolysis, but only in 1 case where apicolysis was not used. Only regular cases were considered, whereas very mild cases, such as slight ptosis of the eyelid, no doubt occur much more frequently. This complication, which then especially occurs in apicolysis cases, is in itself insignificant, and is due to a lesion of the sympathetic trunk. As a rule it is transient; it may, however, last for months and be cosmetically inconvenient for the patient.

A circumstance for which apicolysis has been blamed is that by radical apicolysis the cavity, which is perhaps located in the upper part of the lung, sinks down into the thorax toward the hilum, so that it drops below the area of the extensive collapse and remains here as a residual cavity, the consequence being that the planned thoracoplasty must be extended, or, possibly, that supplementary thoracoplasty must be applied. Analysis of the material with regard to this circumstance shows that open residual cavities were found two months after the operation in 60, out of the 420, cases. In the nonapicolysis group there were 27, or 17 per cent, while the apicolysis group had 33, or 13 per cent. Thus, apicolysis does not seem to have contributed to increasing the number of residual cavities, and in this group the primary healing of the cavity was, at any rate, slightly better. In some cases spontaneous closing of the cavity ensued. As previously stated, supplementary thoracoplasty became necessary in 56 cases, 26 (16 per cent) in the nonapicolysis group, and 30 (11 per cent) in the apicolysis group.

It must be added that supplementary thoracoplasty was not used exclusively in case of residual cavities, but also in case of continuous excretion of bacilli, even if a residual cavity could not roentgenologically be demonstrated with certainty.

CONCLUSIONS

A summing-up of the results of this examination shows that the introduction of apicolysis in connection with thoracoplasty, as it has been used in the Øresundshospital in the period after 1935, has not quite yielded the results expected. Apicolysis was not able to affect the permanent results of the total material. A closer analysis shows, however, that a certain profitable influence cannot be disregarded in a minor, limited field, namely in case of purely apical processes in which a selective minor apical thoracoplasty is indicated.

On the other hand no effect of apicolysis was traceable, on the basis of a considerable material for comparison, for processes in which the cavity was infraclavicular or more basal; and these cases, in which upper-lobe, subtotal, or total thoracoplasty is performed, make up the greater part of the material.

Furthermore, apicolysis seems to involve greater risk of wound infection with subsequent protracted or therapy-resistant thorax fistulas.

Accordingly, for some time to come at any rate, it must be advisable to apply apicolysis only in case of purely apical processes for which a minor apical thoracoplasty is planned.

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INTRAPERICARDIAL ANATOMY IN RELATION TO PNEUMONECTOMY FOR PULMONARY CARCINOMA

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IN 1946, Allison[2] advocated intrapericardial ligation of the pulmonary vessels in performing pneumonectomy for carcinoma of the lung, in order to permit a safer, and yet more radical, operation. In 44 of 102 patients subjected to pneumonectomy for cancer of the lung in the last three years at Jefferson Hospital, the pulmonary arteries and veins were ligated and divided within the pericardial sac. In some of the 44 patients the pericardium was opened because it was easier and simpler to ligate and divide the great vessels in this situation. In many cases, however, pneumonectomy would not have been possible without using the intrapericardial approach. In large hilar tumors it is difficult, if not impossible, to expose the pulmonary veins outside the pericardium. In carcinomas originating in the lower lobe, the pericardium itself may be directly invaded and must be removed. Not infrequently tumor tissue spreads along the wall of the inferior pulmonary vein, or grows in its lumen, completely occluding it. In all such cases it is impossible to remove the growth in its entirety without excising that portion of the pulmonary vein lying outside the pericardium. In several instances the entire pulmonary vein has been removed and the site of entrance of the pulmonary vein into the left atrium closed by suturing the wall of the auricle itself. Occasionally histologic examination of the removed lung has shown that either the pulmonary veins or the bronchus had been divided through cancer tissue. With regard to the bronchus, such unfortunate occurrences can be diminished by dividing the bronchus as far as possible from the growth, in some instances even removing a portion of the trachea. As regards the pulmonary veins, it is obvious that routine division within the pericardial sac, in the case of all hilar growths, will diminish the likelihood of leaving behind neoplastic tissue.

Since surgical procedures within the pericardium are of recent origin, very little of the surgical anatomy of the region has been recorded in the literature. It was thought that dissection of the great vessels within the pericardium in a large number of bodies might reveal some anatomic facts of interest to surgeons.

Dissections were carried out on 185 adult cadavers. Seventy of these were fresh autopsy specimens. Estimates were made of the proportion of the circumference of the pulmonary vessels which lay within the pericardium. That part of the circumference of the great vessels covered by serous pericardium was estimated in tenths of the total circumference. The point of bifurcation of the pulmonary artery, the presence of anomalous pulmonary veins, and the presence or absence of a patent vessel in the fold of Marshall were also observed and

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Received for publication Nov. 18, 1949.

recorded. In 4 cases determinations on the left side were impossible, due in 1 case to a previous pneumonectomy, in the other 3 to tuberculous adhesions. In 1 case a pneumonectomy had been performed on the right, thus preventing determinations being made on that side. The observations were made by a single observer (J. E. H.)

PERICARDIAL SINUSES AND RECESSES

The fibrous covering of the pericardium is attached caudad to the diaphragm, cephalad to the deep cervical fascia, and laterally extends as the adventitial coverings of the great vessels. The parietal layer of serous pericardium lies on the under surface of the fibrous covering, but at the points of both arterial and venous attachments to the heart, it is reflected upon the heart as the visceral layer.

Cephalad, there is a dorsal communication between the right and left sides of the pericardial cavity which is bounded in front by the aorta and pulmonary artery, and behind by the superior vena cava, left atrium, and right pulmonary artery. This is the "transverse sinus" (Fig. 1). Caudalward, another dorsal sinus is present on the posterior aspect of the atria on the left side. It has been termed the "oblique sinus of the pericardium.[21] It is a blind cul-de-sac bounded posteriorly by the parietal pericardium, anteriorly by the atria, cephalad by the pulmonary veins, and on the right side by the inferior vena cava (Fig. 2).

Many unnamed recesses in the pericardial sac have been described by anatomists. Allison described two of these recesses and designated them as a "left pulmonary recess" and a "postcaval recess." The left pulmonary recess is bound cephalad by the left pulmonary artery, caudad by the left superior pulmonary vein, and medially by the vestigial fold of Marshall (Fig. 3). The postcaval recess is located on the right side, and is bounded anteriorly by the superior vena cava, cephalad by the right pulmonary artery, and caudad by the right superior pulmonary vein (Fig. 4). Another recess to which we would like to refer for descriptive purposes may be termed the "right pulmonary recess," located between the superior and inferior pulmonary veins on the right side (Fig. 4).

THE PULMONARY VESSELS

The most cephalic extension of the parietal layer of serous pericardium was found to be upon the aorta. This occurred on the average about 6 cm. above the origin of the aorta from the heart measured on its anterior surface. From this point, the line of reflection on the left side extends over the anterior and inferior surfaces of the left pulmonary artery (Fig. 2). A little more than one-half the circumference of the artery is easily visible (Table I). The serous pericardium then descends caudad and reflects upon the superior, anterior, and inferior surface of the left superior pulmonary vein, leaving about two-thirds of this vessel's circumference accessible within the sac. Continuing caudalward the serous layer now reflects upon the superior, inferior, and anterior surfaces of the left inferior pulmonary vein. This vessel is the most prominent of all, four-fifths of the circumference bulging into the pericardial sac (Table I).

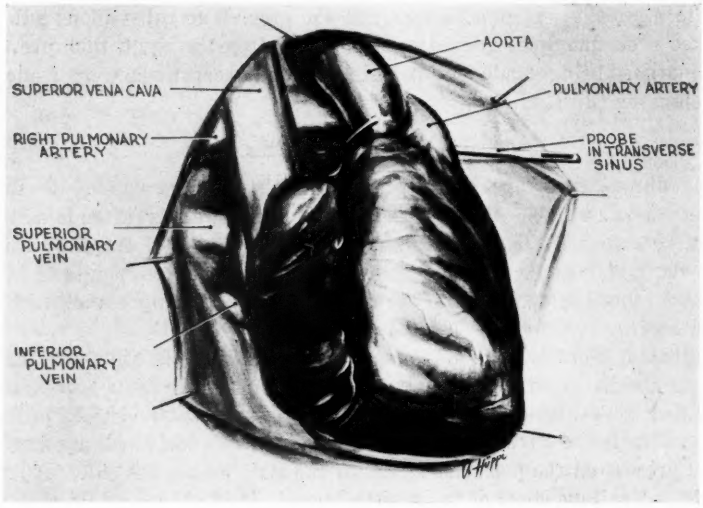

Fig. 1.—Drawing illustrating the transverse sinus and the reflections of the serous pericardium on the right side. A probe is inserted into the transverse sinus pulling the aorta and pulmonary artery to the left.

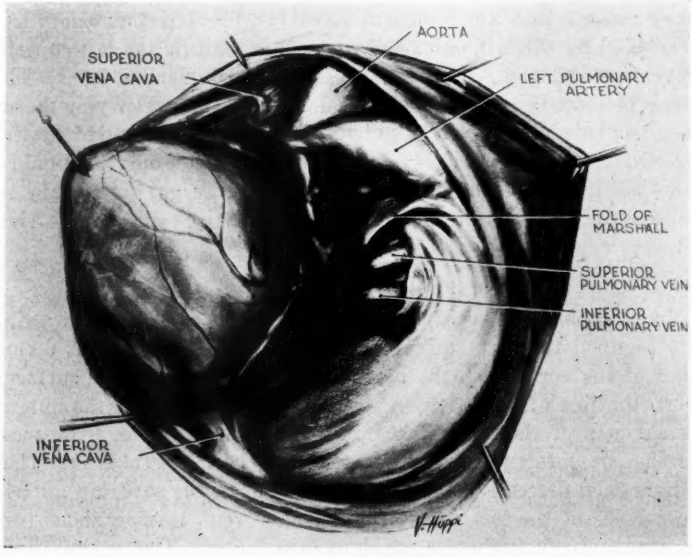

Fig. 2.—The oblique sinus and the serous reflections on the left side of the pericardial sac. Apex of the heart is pulled upward and to the right.

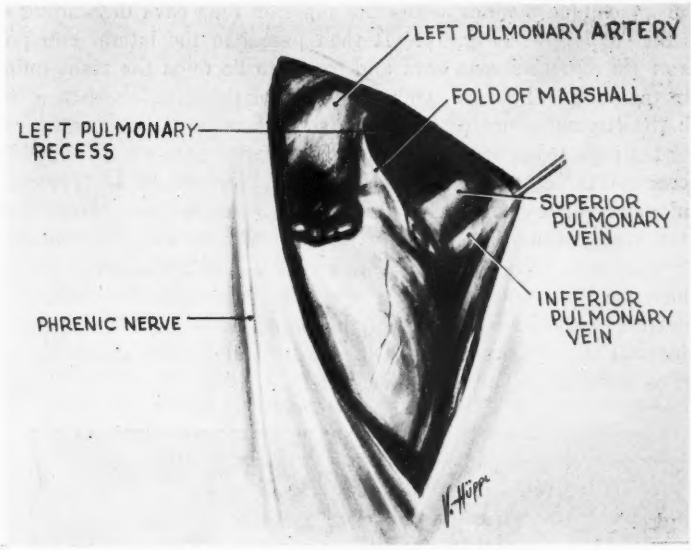

Fig. 3.—The left pulmonary recess.

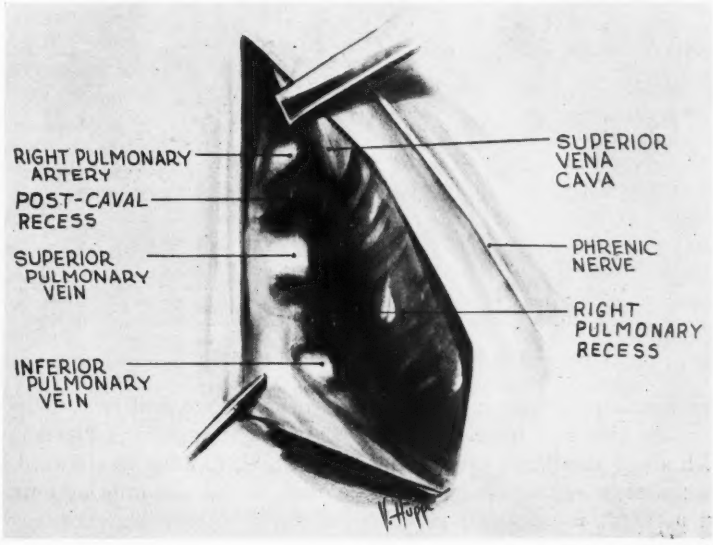

Fig. 4.—Right side of the pericardial sac revealing the postcaval and right pulmonary recesses.

On the right side, beginning cephalad on the aorta, the pericardium is reflected in an oblique manner across the superior vena cava descending caudad from medial to lateral (Fig. 1). It then passes to the lateral and posterior surfaces of the superior vena cava and comes to lie upon the right pulmonary artery in the postcaval recess. Only a portion of the anterior surface, or about one-fifth the circumference of the latter vessel is seen at this point. In eight instances the pericardial reflection upon the superior vena cava occurred so low that access to the postcaval recess (Fig. 4) was impossible. In these cases the right pulmonary artery was excluded from this recess, but was readily accessible in the transverse sinus, where it runs transversely posterior to the aorta and superior vena cava (Fig. 1). In fact, we have been impressed with the ease with which the right pulmonary artery may be exposed in this location. Here three-quarters of the circumference of the right pulmonary artery projects into the pericardial sac as compared with the projection of about one-fifth of the circumference in the postcaval recess (Table I).

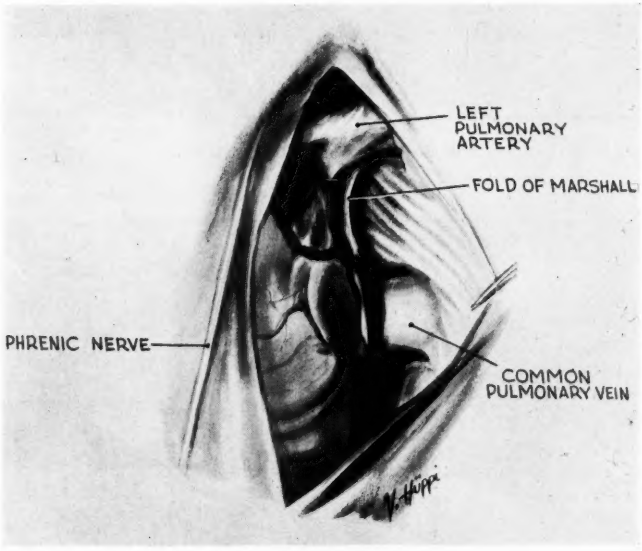

Fig. 5.—Left common pulmonary vein.

The serous pericardium then descends in the recess and reflects upon the superior, anterior, and inferior surfaces of the right superior pulmonary vein, of which about two-thirds projects into the sac. Continuing caudalward in the right pulmonary recess, the pericardium then covers the inferior pulmonary vein in part. In approximately one-half of the specimens this vessel could not be seen within the pericardial sac. When it was visible only about one-third of the circumference could be seen. The serous layer then descends to the diaphragm.

TABLE I. PROTRUSION OF PULMONARY VESSELS INTO THE PERICARDIAL SAC
(Left Side 181 Cases, Right Side 184 Cases)

VESSEL	NUMBER OF CASES WITH VESSELS FOUND IN PERICARDIUM		CIRCUMFERENCE OF VESSEL IN PERICARDIUM	
	LEFT SIDE (PER CENT)	RIGHT SIDE (PER CENT)	LEFT SIDE (PER CENT)	RIGHT SIDE (PER CENT)
Superior pulmonary vein	75	97	67	62
Inferior pulmonary vein	75	46	82	30
Common pulmonary vein	25	3	88	50
Pulmonary artery	100	99*	57	72*
		94†		21†

*In transverse sinus medial to superior vena cava.
†In postcaval recess lateral to superior vena cava.

VENOUS ANOMALIES

The reflections upon the left pulmonary veins as described previously occurred in 135 of the 181 bodies observed. In 46 cadavers (25 per cent) the left pulmonary veins merged to form a common trunk which entered the left atrium (Fig. 5). When this single trunk was present on the left side, more than four-fifths of its circumference protruded into the pericardial sac (Table I). On the right side we have seen six common pulmonary veins (3 per cent), and about one-half of the circumference of each of these was visible within the pericardium.

TABLE II. INCIDENCE OF COMMON PULMONARY VEINS

AUTHOR	TOTAL BODIES	LEFT COMMON PULMONARY VEIN		RIGHT COMMON PULMONARY VEIN	
	(NUMBER)	(NUMBER)	(PER CENT)	(NUMBER)	(PER CENT)
Adachi	91	5	5.5	6	6.6
Healey and Gibbon	185	46*	25.4	6†	3.3

*One hundred eighty-one bodies studied.
†One hundred eighty-four bodies studied.

Von Sommerrung[27] stated that a common pulmonary vein was more frequently found on the left side. Goeppert[12] in his earlier writings stated that the pulmonary veins joined to form a common trunk more frequently on the right side, but retracted this statement in his later articles. Adachi[1] found 11 common pulmonary veins in 91 cadavers. Table II summarizes our findings and those of Adachi. A left common pulmonary vein was present in about one-fifth of the bodies, while a right common pulmonary vein was present in less than 5 per cent. Aside from Adachi's report, no other statistical study could be found in the literature.

TABLE III. SITE OF FORMATION OF COMMON PULMONARY VEINS

	HEALEY AND GIBBON		ADACHI	
	(NUMBER)	(PER CENT)	(NUMBER)	(PER CENT)
Intrapericardial	4	8	0	0
At edge of sac	40	77	6	55
Extrapericardial	8	15	5	45

These common pulmonary veins may be formed outside of the pericardium, at the edge of the pericardial sac, or within the pericardium. Table III lists the site of junction of the superior and inferior veins to form a common trunk in our 52 cases and in Adachi's 11 cases. In the great majority of cases, the common pulmonary vein was formed at the edge of the pericardial sac.

Another venous anomaly was encountered in 3 of the 185 dissections. In these bodies three separate vessels entered the left atrium, one from each lobe of the right lung. Brantigan[5] described 2 such cases which he observed at operation.

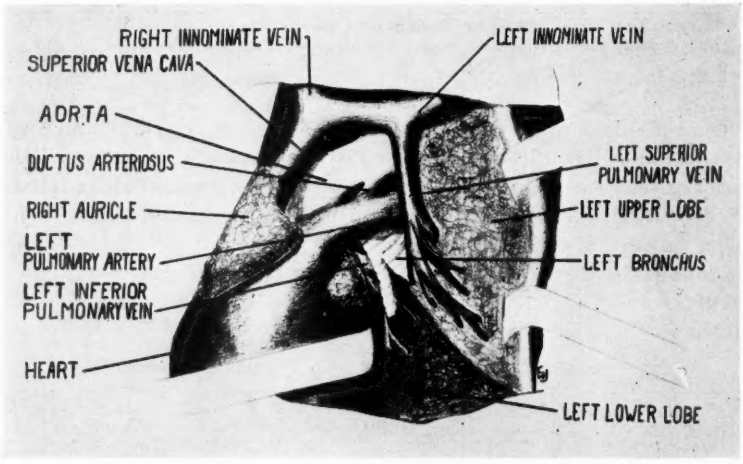

Fig. 6.—Anomalous vessel found in our dissections. Left superior pulmonary vein drains into the left innominate. The left inferior pulmonary vein follows its normal path of drainage into the left atrium.

In one of our dissections we encountered an interesting anomalous connection between the pulmonary and systemic venous system (Fig. 6). This consisted of a large vein draining the entire upper lobe of the left lung and emptying into the left innominate vein. The inferior pulmonary vein entered the left atrium in its usual manner. Brody[6] in a review of the literature found 68 cases in which there was a partial drainage of pulmonary venous blood into the systemic venous system. Eight of the 68 cases were similar to the one just described. Since that time one other case has been reported by Hughes and Rumore.[15] The embryologic basis of these anomalous communications between the pulmonary and systemic systems and the variations in the number of pulmonary veins entering the left side of the heart has been adequately discussed by Brown,[7] Patten,[23] and Brantigan.[5]

THE FOLD OF MARSHALL

Allison[2] stated that "one may further free the upper (left pulmonary) vein by dividing the fold of Marshall." This fold is located between the pulmonary artery and the left superior pulmonary vein (Fig. 2) and contains the ligament

of the left superior vena cava. This ligament, along with the highest intercostal vein on the left side, and the oblique vein on the left atrium, are the remnants of the embryologic left superior vena cava.[18] These changes come about as illustrated in Fig. 7. The right and left anterior cardinal veins communicate about the eighth week, and the venous blood is thereby shunted to the right side. This oblique channel becomes the left innominate vein. The remainder of the left anterior cardinal vein may then be divided as to its future development into three portions; the most cephalic portion becomes the highest intercostal; the medial portion, the ligament of the left superior vena cava; the caudal portion, the oblique vein of Marshall. Conditions may be such, however, that the more primitive structures remain as a left superior vena cava.

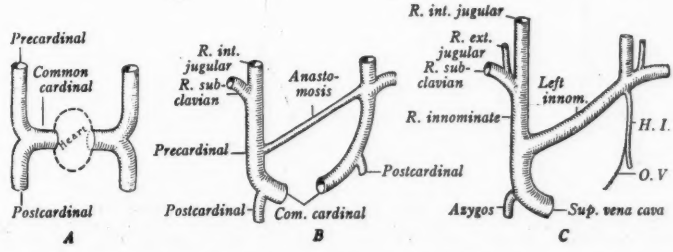

Fig. 7.—Illustration showing the transformation of the cardinal veins of human embryos. *A*, at six weeks; *B*, at eight weeks; *C*, adult. *H.I.*, highest intercostal; *O.V.*, oblique vein of the left atrium. (Reproduced from Arey's "Developmental Anatomy," Philadelphia, 1946, W. B. Saunders Co., with permission of the author and publishers.)

This vessel may be present with or without the presence of the right superior vena cava. The latter is rare and is termed "situs inversus of the superior vena cava." Halpert[14] has reviewed these cases and found only 23 in the literature up to 1942. Since that time 2 additional cases have been reported.[4, 26] When the right superior vena cava is present, the left is usually of small size. Chouke,[9] in 1939, in reviewing the literature, found a total of 205 cases of persistent left superior vena cava. He failed to mention, however, the 4 cases cited by Adachi[1] in 1933, and the case reported by Mergoni[20] in 1938. We have found reference to 12[8, 10, 11, 13, 16, 17, 19, 22, 24, 25, 26] in the literature from 1939 to date, and have found 3 in our dissections, bringing the total number to 225 cases of persistent left superior vena cava. Each of the persistent left superior vena cavae in our series were very small in caliber. They were all patent throughout as demonstrated by injection of dye. All were continuous below with the coronary sinus. Two communicated above with the highest intercostal vein and one communicated directly with the left innominate vein (Fig. 8).

We have searched for a patent vessel in the fold of Marshall in 91 cadavers and have found twelve. Three of these, described previously, were patent throughout. The remaining 9 were continuous below with the oblique vein of the left atrium, but extended cephalad only to the superior extension of the vestigial fold. These anomalies must be borne in mind when proceeding to divide the fold as Allison suggests.

An interesting relationship exists between the vestigial fold and the bifurcation of the pulmonary artery. Of the 181 bodies observed, the bifurcation occurred at the point of attachment of the fold to the pulmonary artery in 98. The artery bifurcated medial to the attachment in 56 cases, and on the lateral side of the fold in 14 cases. No fold could be found in 13 bodies.

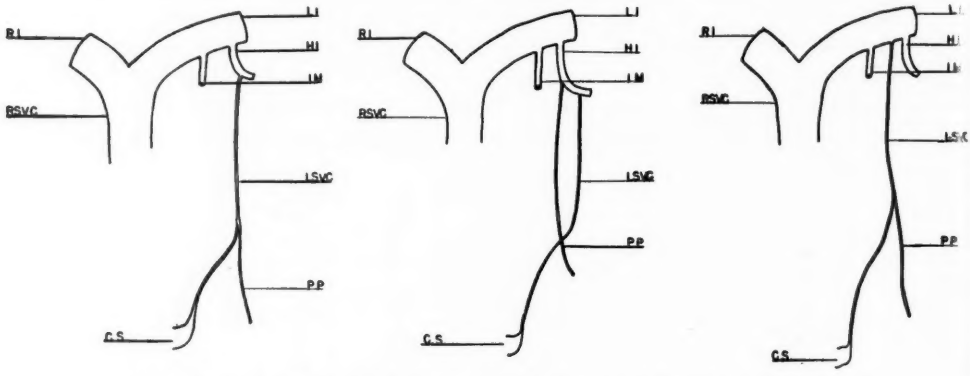

Fig. 8.—Three cases of persistent left superior vena cava observed in our dissections. *RI*, right innominate; *LI*, left innominate; *RSVC*, right superior vena cava; *HI*, highest intercostal; *IM*, internal mammary; *LSVC*, left superior vena cava; *PP*, pericardio-phrenic; *CS*, coronary sinus.

DISCUSSION

With regard to the sinuses and recesses of the pericardium, it should be borne in mind that the right pulmonary artery is readily accessible in the transverse sinus between the superior vena cava and the aorta. Approximately three-fourths of the circumference of the vessel lies within the pericardial sac in this location. Where there is a large growth in the right main bronchus or the right upper lobe it may be difficult to expose a sufficient length of the pulmonary artery lateral to the superior vena cava to ligate and divide the vessel safely. In such cases the right pulmonary artery can be easily exposed by retracting the vena cava laterally and ligating and dividing the vessel between the vena cava and the aorta. In a patient, operated upon by one of our associates (F. F. Allbritten, Jr.), exposure and ligation of the artery in this location proved to be a lifesaving measure. Exposure was difficult because of a large tumor mass and hemorrhage occurred from the stump of the pulmonary artery, which had been ligated and divided lateral to the superior vena cava. The hemorrhage was controlled by digital pressure. The proximal portion of the vessel was then easily exposed by retracting the vena cava laterally, and the artery was safely ligated in this position.

The extent to which the pulmonary veins are covered by the serous layer of the parietal pericardium (Table I) is of minor surgical significance, as in order to pass a ligature around any of the pulmonary veins within the pericardium, the pericardial sac must be penetrated both above and below the vessel being ligated.

It should be borne in mind that, on the left side, the superior and inferior pulmonary veins join to form a common trunk within the pericardial sac in about one-fifth of all individuals. This simple and common anatomic variation has not been sufficiently emphasized in the past. The presence of anomolous connections between the pulmonary and systemic veins are relatively rare, but the possibility of such connections should not be forgotten. The three persistent left superior venae cavae encountered in our dissections were all small, though patent, and would not have proved troublesome to the operating surgeon.

SUMMARY

1. The intrapericardial anatomy in 185 adult cadavers has been studied. The usual anatomic findings and the common variants have been tabulated and illustrated.

2. It is suggested that, in performing pneumonectomy for cancer of the lung, except in the early cases or the peripheral growths, intrapericardial ligation and division of the pulmonary vessels will provide a wider margin of safety beyond tissues grossly involved by the tumor.

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MUCOCELLULAR PAPILLARY ADENOCARCINOMA OF THE LUNG

Lobectomy, Five-year Follow-up

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IN AUGUST, 1946, we reported a case of "Mucocellular Papillary Adenocarcinoma of the Lung,"[1] treated by lobectomy. The purpose of the report was twofold: first, to set forth the distinctive microscopic features of the lesion, and second, the multilocular character and pronounced circumscription of the tumor, occupying most of the lower lobe.

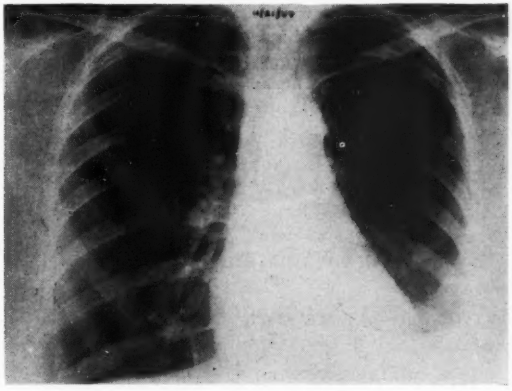

Fig. 1.—Nov. 21, 1949, film five years after operation. Elevated diaphragm due to phrenic nerve severance at operation.

To summarize the case, the patient was 44 years old, female, first seen by us in 1944. There was a history of cough starting in 1941, which became productive in 1943. Physical examination showed that the lungs were clear except beneath the left scapula where an area of dullness was detected at the level of the fifth thoracic vertebra. There was clubbing of the fingers. Roentgenogram of the chest showed a homogeneous density in the left lower lobe, circumscribed and lobulated. An exploratory thoracotomy was performed in November, 1944. At operation, the left lower lobe was found to be greatly expanded by a circumscribed lobulated tumor. There was no cancerous involvement of the pleura or any of the hilar lymph nodes. A dissection lobectomy of the left lower lobe was performed. The pathology report was mucocellular papillary adenocarcinoma of the lung, histologically of the type of the multicentric papillary adenocarcinoma. The report of this case was made two years after operation, at which time the patient was symptom free.

In a paper entitled, "Alveolar Cell Carcinoma of the Lung (Pulmonary Adenomatosis, Jagziekte)," Delarue and Graham[2] stated in reference to our

Received for publication Dec. 30, 1949.

case, "The result seems to indicate that a two-year period of freedom from manifestation of symptoms after lobectomy gives no assurance of complete eradication of the disease." It is, therefore, of interest to report a follow-up on our patient, five years after operation in November, 1944. The patient has been seen at intervals during these five years. In November, 1949, the patient, 49 years of age, was symptom free. Physical examination showed weight to have remained stationary (128 pounds). Hemoglobin was 14.6 Gm. No clubbing of fingers. No adenopathy. No excursion of the left leaf of the diaphragm, as evidenced by percussion and fluoroscopy (phrenic nerve severance at operation). The lungs were clear and resonant. Roentgenogram of the chest taken Nov. 21, 1949, was negative (Fig. 1). The branches of the pulmonary artery were seen to be spread somewhat to follow the expanded upper lobe.

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THORACOPLASTY AND STREPTOMYCIN IN THE TREATMENT OF TUBERCULOUS EMPYEMA

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THE treatment of tuberculous empyema has long been characterized by poor results. Since streptomycin became available in adequate quantities at Fitzsimons General Hospital late in 1946, a distinct evolution in the surgical management of pulmonary tuberculosis at this hospital has developed. The time interval from the onset of the disease to the application of thoracoplasty has been appreciably shortened. Many patients with cavernous caseopneumonic disease have responded to streptomycin therapy with a marked resolution of the exudative element making thoracoplasty feasible at a relatively early period in the disease process.[1] A definite improvement has also been reflected in the results obtained in the treatment of tuberculous empyema.

This report pertains to a consecutive group of 22 patients having tuberculous empyema treated by extrapleural thoracoplasty and streptomycin during the period Dec. 1, 1946, to Aug. 1, 1948. In all instances the pleural fluid was purulent and on culture was positive for acid-fast bacilli in 20 of the 22 patients. The following classification of tuberculous empyema is used in this hospital and is as follows:

1. Tuberculous empyema with no evident parenchymal disease.
2. Mixed (that is, pyogenic plus acid-fast bacilli) tuberculous empyema with no evident parenchymal disease.
3. Tuberculous empyema with parenchymal disease.
4. Mixed tuberculous empyema with parenchymal disease.

In our series, 7 of the patients are in Group 3 and 15 in Group 4. No patients were in Group 1 or 2. All patients in Group 4 were seriously ill. As experience increased in the use of streptomycin the time interval between the onset of the empyema and the application of thoracoplasty in conjunction with streptomycin was gradually decreased. Ten of the surviving patients in Group 4 have had arrest of their parenchymal disease and obliteration of the empyema space. An illustrated case report among Group 4 patients includes the following:

CASE 1.—A 24-year-old male soldier gave a history of pneumonia in 1942, from which he recovered without complications. There were no other serious illnesses and no history of contact with tuberculosis until 1947. While stationed in Germany in January, 1948, he began to complain of undue fatigue, productive cough, blood-tinged sputum, and chest pain. He was immediately hospitalized. On the day following admission he had a sudden onset of severe dyspnea, hemoptyses, chills and fever, and marked prostration. Roentgenograms confirmed the presence of a spontaneous pneumothorax with approximately 50 per cent collapse of the lung with large cavitation in the left upper lobe. Daily thoracentesis with the removal of air and fluid was accomplished with moderate relief of symptoms. Closed tube

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Received for publication Jan. 5, 1950.

intercostal drainage was established in January, 1948, and discontinued while enroute to the United States in February, 1948. On Feb. 27, 1948, he was admitted to Fitzsimons. Roentgenograms of the chest revealed a fluid level in the left pleural space, large cavitation on the left, considerable collapse of the left lung, and slight shift of the mediastinum to the right (Fig. 1). Thoracentesis was carried out every other day with the removal of 500 to 1,000 c.c. of thick greenish fluid having a specific gravity of 1.021 which was positive on culture for acid-fast bacilli. One-half gram of streptomycin was placed in the pleural space each time fluid was removed. The patient improved symptomatically with a sustained decrease in fever, better appetite, and a lessening in the accumulation of fluid. Penicillin therapy, 300,000 units in oil daily, was started two days prior to and continued for six days after

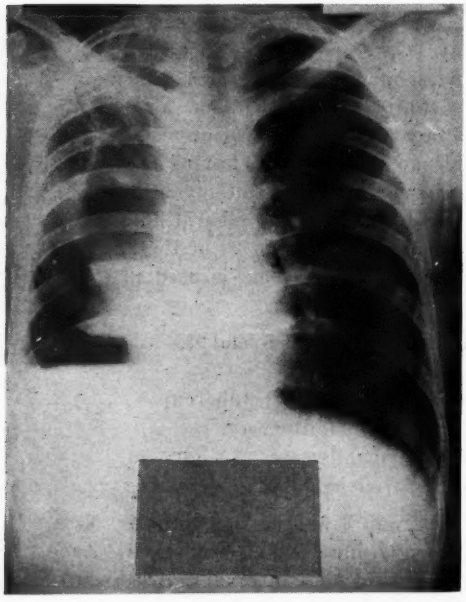

Fig. 1.

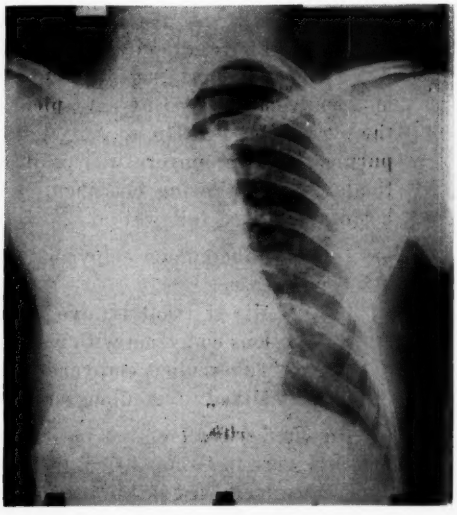

Fig. 2.

Fig. 1 (Case 1).—Spontaneous pneumothorax, cavitation, and mixed infection, tuberculous empyema, left.

Fig. 2 (Case 1).—Postthoracoplasty. No cavity. No empyema.

each stage. A first-stage posterolateral thoracoplasty was performed April 27, 1948. Ten days later an anterior-stage thoracoplasty was performed. Further staged posterolateral thoracoplasties were accomplished until a ten-rib thoracoplasty had been completed May 18, 1948, with removal of all of the first five ribs and long segments of the sixth to tenth ribs, inclusive. The pleural space was kept dry by frequent thoracentesis between operative stages. Streptomycin intramuscularly, 1 Gm. daily, had been started March 29, and was continued for eighty-seven days. The exudative element of the pulmonary disease showed considerable resolution and by May, 1948, there was no evidence of pleural fluid. Eighteen months after the completion of thoracoplasty the patient was asymptomatic, afebrile, and had no cough or sputum production. Numerous gastric washings have been negative for acid-fast bacilli. X-ray examination of the chest revealed no evidence of parenchymal cavitation, the pleural space was obliterated, and the patient was considered in the arrested phase in reference to tuberculosis (Fig. 2).

There have been four deaths among the 15 patients of the Group 4 classification and no deaths among the Group 3 patients. The over-all fatality rate for the 22 patients with tuberculous empyema and parenchymal disease was 18 per cent. This compares most favorably with the data reported from this hospital by Leaver and Hardaway in 1937, as they reported a mortality rate of 70.9 per cent in 24 patients suffering from mixed tuberculous empyema and 22.9 per cent in 35 patients having a tuberculous empyema.[2] The deaths in our series presented conditions which to date we have been unable successfully to overcome. One patient, a 21-year-old soldier, developed a postpneumonic empyema while a prisoner of war in Germany. Several operative procedures including an extensive decortication and unroofing of the empyema cavity were accomplished. The diagnosis of tuberculosis was made by the examination of the surgical specimen of diseased pleura. Streptomycin was first given two years after the onset of the illness. He died three years after his first operation performed while a prisoner of war in 1944. Post-mortem examination revealed widespread tuberculous involvement of the viscera. A second death occurred in a patient who was a severe drug addict and had been chronically ill for twelve years with pulmonary tuberculosis. He died on the fourth postoperative day following a first-stage thoracoplasty. The third patient died approximately one year after obliteration of the empyema cavity by thoracoplasty, from progressive contralateral tuberculous disease with giant cavitation. Post-mortem examination revealed that the empyema space had been obliterated. The fourth death occurred in a 51-year-old man who had had pulmonary tuberculosis treated by artificial pneumothorax for 22 years. He had a first-stage thoracoplasty performed six months after the onset of a mixed infection empyema and died from a coronary thrombosis on the eleventh postoperative day.

Ten patients with mixed tuberculous empyema and parenchymal disease have arrested their disease and have had no reactivation during an average period of 24.5 months following thoracoplasty with streptomycin therapy. The shortest follow-up period was 14 months, the longest 32 months. One patient had active tuberculous disease in the contralateral lung 18 months following thoracoplasty. The empyema space had been obliterated.

Seven patients were in Group 3, that is, pure tuberculous empyema with parenchymal disease. Six patients have had arrest of their parenchymal disease and no evidence of empyema since operation. The average length of the follow-up period has been 18.4 months. The shortest period was 13 months, the longest 29 months. The following case report of this group which has not had arrest of the disease process is recorded.

CASE 2.—A 32-year-old white male soldier contracted malaria, in 1942, on Bataan and was seriously ill. He was later captured by the Japanese and while a prisoner of war in the Philippine Islands he developed beriberi and lost approximately 40 per cent of his normal weight during imprisonment. He was liberated on Aug. 20, 1945. In March, 1947, he was hospitalized complaining of symptoms of nasal sinusitis, sensation of fullness in the right ear, a moderate cough productive of one teaspoonful of whitish sputum, weight loss, and generalized fatigue. Roentgenograms of the chest revealed a massive pleural effusion in the left

hemithorax and a large 5 by 8 cm. cavity in the left upper lung field (Fig. 3). He was transferred to Fitzsimons General Hospital April 10, 1947. Sputa were positive on culture for acid-fast bacilli. Thoracenteses twice weekly resulted in gradual diminution in the amount of pleural fluid. He received streptomycin 2 Gm. daily from June 14, to Aug. 6, 1947, when it was discontinued due to marked dizziness. He was restarted in the dosage of 1 Gm. per day on August 14, and continued until Nov. 3, 1947. By the end of the first course of streptomycin the patient's symptoms had markedly decreased (Fig. 4). Because of the persistent empyema and cavitation, thoracoplasty was performed with removal of seven ribs in three stages at intervals of 21 days. The last stage was performed on April 8, 1948. Penicillin was given as in the first case. A total of 294 Gm. of streptomycin was given. A follow-up report, eighteen months postoperatively from a Veterans Hospital indicated that sputum was positive but no empyema space was demonstrable. Lobectomy of the left upper lobe may be advisable.

Fig. 3.

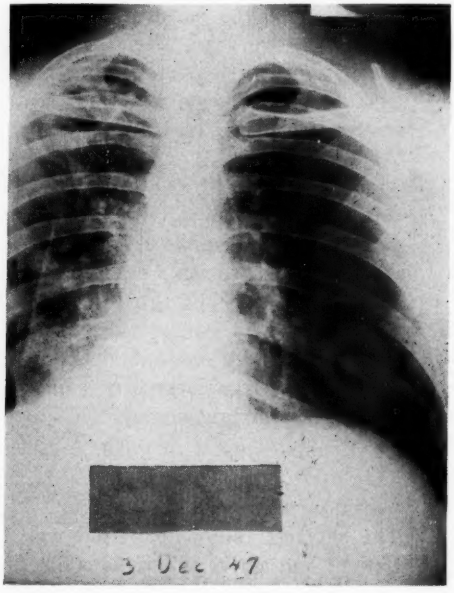

Fig. 4.

Fig. 3 (Case 2).—Giant parenchymal cavity, empyema, left.

Fig. 4 (Case 2).—Prethoracoplasty. Considerable clearing of parenchymal lesions and of empyema.

The changing concepts of therapy and improvements in the management of pulmonary tuberculosis are, we believe, partially reflected in analyzing the precipitating causes of tuberculous empyema noted in this series of patients. The earlier abandonment of an unsuccessful pneumothorax, the earlier application of thoracoplasty in streptomycin treated patients, and the wider acceptance of excisional surgery in this disease are encouraging. In our series of 22 patients, 14 developed a tuberculous empyema as a direct accompaniment of their disease unrelated to any therapeutic efforts. Of this group, 3 developed from a massive pleural effusion, 8 following a spontaneous

pneumothorax, 1 in association with a tuberculous pneumonia, and 2 were of gradual onset without any demonstrable exciting cause. Eight of the series were associated with therapeutic efforts, 7 patients were under treatment by artificial pneumothorax therapy, and 1 followed extrapleural thoracoplasty for parenchymal disease before the availability of streptomycin. During the period of this report 173 patients received 509 stages of extrapleural thoracoplasty, 63 patients received closed intrapleural pneumolysis, and 25 patients had lobectomy, partial or complete, or pneumonectomy performed at Fitzsimons in the treatment of pulmonary tuberculosis.

Therapy in relation to the type of onset and the presenting pathology of the empyema is significant. Patients with a sudden onset, a spontaneous pneumothorax, bronchopleural fistula, and rapid reaccumulation of fluid or extreme sepsis may require open or closed drainage as a lifesaving measure. Seven of our patients belonged in this group. They were all in Group 4 and were critically ill. In 8, the onset of the empyema was sudden but did not require open or closed drainage. The accumulation of empyema fluid in these patients was kept under control with frequent aspirations so that thoracoplasty could be completed without recourse to drainage. It was in this group that streptomycin and early thoracoplasty markedly lessened the morbidity. Seven had a mixed infection empyema and 1 had a pure tuberculous empyema. The patients who had a gradual onset of the empyema did not receive drainage before thoracoplasty.

We have had only limited experience with decortication for the treatment of tuberculous empyema. The encouraging results reported by Weinberg and Davis[3] offer further hope for improving the results in the treatment of this condition.

SUMMARY

Tuberculous empyema is still a dreaded complication of pulmonary tuberculosis. The employment of streptomycin in conjunction with extrapleural thoracoplasty has appreciably decreased the mortality rate in tuberculous empyema. The general trend in the earlier application of extrapleural thoracoplasty and the judicious use of excisional surgery along with streptomycin in the management of pulmonary tuberculosis constitutes, we believe, major advances in the therapy of this disease. The results in the treatment of 22 consecutive patients with tuberculous empyema with thoracoplasty and streptomycin is very encouraging. The mortality rate was 18 per cent. Seventeen are alive and their disease arrested. One patient still has active parenchymal disease. The postoperative follow-up period in the entire group varies from 13 to 32 months.

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OBSERVATIONS ON THORACOPLASTY DURING PREGNANCY

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INTRODUCTION

THE revolutionary improvements in medicine in recent years are reflected in the present-day change of outlook on the reciprocal relationship of pregnancy and tuberculosis. Not only has this study gained fresh impetus thereby, but modern concepts of its cognate problems have emerged. By and large, the proprieties of the combined conditions are now generally accepted, the pregnancy assuming a secondary role to that of the associated lung lesion. As a result the value of collapse therapy, both prophylactically for the child, and curatively for the mother, has become considerable. Nevertheless, publications relating to thoracoplasty during pregnancy are singularly few. As yet, only four isolated instances have been reported in international literature (quoting Seeley and associates, 1940). To date, McIntyre (1948) has made the sole contribution to British literature. Accordingly the following examples of thoracoplasty during pregnancy were considered worthy of putting on record in view of their exceptional interest, and the fact that they might contribute to the status of collapse therapy in the pregnant tuberculous patient, as yet, not definitely defined.

ILLUSTRATIVE CASES

Case 1.—Mrs. M. O'D., aged 38 years. This patient, four and one-half months pregnant, was admitted to Robroyston Hospital, Glasgow, on April 20, 1948, complaining of a productive cough of several weeks' duration.

In 1947, she received sanatorium treatment for a left-sided, active lung lesion. Attempts to establish a left artificial pneumothorax were unsuccessful and consequently a left-sided phrenic nerve interruption was performed. At her own request, she was dismissed from the sanatorium prematurely, after six months' institutional treatment. Her health, for several months following this discharge, was indifferent, cough, tiredness, and night sweats being present.

On admission to Robroyston Hospital her general condition was found to be fairly good. The lung lesion, clinically, was dominantly left sided in distribution, and fibrocaseous in type. This was confirmed by the radiologist who reported no definite disease seen in the right lung. There was marked pleural thickening on the left side. The mediastinum was drawn to the left. Bacteriologic examination of the sputum revealed the presence of many tubercle bacilli. The sedimentation rate was 20 mm. at the end of one hour (Westergren). But for a slight displacement of the heart to the left, clinical examination of other vital organs revealed no gross abnormality. Following induction by sodium pentothal (0.5 Gm.) intravenously, and under general anesthesia maintained by nitrous oxide oxygen and Trilene, administered endotracheally, a two-staged thoracoplasty was performed. The first stage was done on April 23, 1948, the second, May 10, 1948. Seven ribs in all were removed, subperiosteally. No undue bleeding was noticed during these operations, both of which were well tolerated by the patient.

From the Robroyston Hospital.
Received for publication Jan. 13, 1950.

On Sept. 7, 1948, the patient was delivered spontaneously without anesthesia, of a live, male child, weighing 6 pounds, 12 ounces. The total duration of labor was fourteen hours, thirty minutes, the placenta and membranes were expelled completely and spontaneously. The condition of mother and child after delivery was excellent. The puerperium was normal and uneventful.

One year, approximately, following delivery, mother and child reported for examination. Roentgenograms taken of the mother's chest showed no deterioration of the lung lesion. The intradermal tuberculin sensitivity test (1:1,000) in the child was negative.

CASE 2.—Mrs. J. S., aged 28 years. This patient, approximately five months pregnant, was admitted to Robroyston Hospital, Glasgow, on July 7, 1948. Several weeks prior to admission she complained of slight pain, localized to the left posterior chest wall. Morning cough accompanied by scanty sputum, mucoid in character, was also present.

In 1947, she received sanatorium treatment for an active, left-sided lung lesion, namely, bed rest supplemented by a left side phrenic nerve interruption. Attempts at artificial pneumothorax on this same side had been tried without success.

On the patient's admission to Robroyston Hospital the lung lesion, clinically and radiologically, was found to be fairly fibrotic, but a cavity was present over the left apex and she had a positive sputum. Sedimentation rate was 18 mm. at the end of one hour (Westergren). Clinical examination of other vital organs failed to reveal any abnormalities. Pelvic examinations confirmed the pregnancy but did not disclose any obvious cause for an abortion in 1946.

The first stage of a left-sided, seven-rib thoracoplasty was performed on July 12, 1948, the second being completed fourteen days later. No complications were encountered during both operative procedures, and recovery was uneventful.

On Nov. 19, 1948, this patient had a spontaneous delivery at full term of a live, male child, after a labor which lasted ten hours, thirty minutes. The placenta and membranes were expelled completely, spontaneously, ten minutes later. The birth weight of the child was 5 pounds, 3 ounces.

Examination of the mother and child ten months after the confinement was satisfactory. Roentgenograms of the mother's chest showed no progression of the disease, sedimentation rate was 4 mm. (Westergren), and sputum remained negative for the tubercle bacillus. The intradermal tuberculin sensitivity test (1:1,000) in the child was negative.

CASE 3.—Mrs. S. McC., aged 28 years. This patient, five months pregnant, and complaining of a slight unproductive cough, was admitted to Robroyston Hospital, Glasgow, on Feb. 13, 1949. The lung lesion, confined to the right upper zone, was fairly fibrotic in type with cavity formation, and sputum was positive for the tubercle bacilli. Sedimentation rate was 14 mm. at the end of one hour (Westergren).

In 1943, she received routine sanatorium treatment for ten months, including right-sided artificial pneumothorax and phrenic nerve interruption to this same side. Duing the years 1943 to 1949, following discharge, she was remarkably well. On admission to Robroyston Hospital, Glasgow, she was in good general state. Clinical investigation did not reveal any abnormality of the other vital organs. Pelvic examination confirmed the presence of a five months' pregnancy and a contracted pelvis, the presumed cause of a protracted labor with death of the child in 1948. Because of a very great desire on her part to have a live child, and the fact that the lung lesion was dominantly productive in type, unilateral in distribution, general condition being reasonably good, a right-sided thoracoplasty was advised. The first stage was performed on Feb. 14, 1949, the second on Feb. 28, 1949. No complications were met. On May 25, 1949, following artificial rupture of the membrane, patient was delivered, spontaneously, after preliminary episiotomy, of a live female child, weighing 6 pounds, 8 ounces. Duration of labor was three hours, fifty-five minutes. Placenta and membranes were expelled completely, spontaneously, in ten minutes. The puerperium was normal and uneventful.

A follow-up study, approximately three months after delivery, gave gratifying results. Mother and child were both alive and well. No deterioration in the mother's lung lesion was reported by the radiologist. The child weighed 12 pounds, 2 ounces and was obviously thriving. The Mantoux test was negative (1:1,000).

DISCUSSION

The cause and effect relationship of pregnancy and tuberculosis has been a perennial topic for discussion, opinions on the subject varying between wide extremes. Thus, while many maintain that pregnancy influences the course of pulmonary tuberculosis adversely, others believe the converse. In a large series of pregnant and nonpregnant patients, Ornstein and Kovnat (1935) recorded a death rate of 35 per cent among the former, 33 per cent among the latter, the difference in the comparative mortality figures being negligible. This was confirmed by Hill (1928), Barnes and Barnes (1930), Marshall (1931), and Forssner (1924). By and large, the character of the associated lung lesion rather than the pregnancy is now considered the more important factor in prognosis. Moreover, much medical evidence can be adduced to show that with the institution of appropriate and adequate nursing and medical attention, under ideal environmental conditions, early in the antenatal period, pregnant patients with active phthisis need not now fare worse than their nonpregnant sisters. From the results of investigations on twenty-six pregnant patients, treated by artificial pneumothorax, Cutler (1944) concluded that the risks run by the pregnant patient, who is also tuberculous, are commensurate with the quality of the lung collapse obtained from such treatment. Conceding this point, the next logical step in rational therapeutics must surely be the application of other avilable measures designed to stabilize the diseased process in the lung. In theory, at least, and provided the patient is in good general state, thoracoplasty should be considered for those pregnant patients in whom simpler measures of collapse therapy have previously been tried but have met with no success. Ironically enough, reports on this aspect of the management of the pregnant tuberculous patient are very few. Accordingly, to date, it would seem that the compatibility of thoracoplasty during pregnancy is not generally recognized.

In this present study, not only the practicability, but also the immense prophylactic potentialities of this principle are illustrated. Figures presented, however, are of no importance statistically. On the basis of this investigation, therefore, recommendations for thoracoplasty during pregnancy can only be tentative.

Albeit, the fact that international and national literature, alike, have ignored or lightly dismissed this aspect of the problem as impracticable, results recorded are not to be deprecated. Furthermore, by accepting the author's conclusions that where desirable thoracoplasty during pregnancy may also be technically feasible, a fresh field of speculation on this vexed question of pregnancy and tuberculosis is presented. Unfortunately it is not within the scope of this short monograph to discuss in detail the many variables complicating

this problem. Of necessity, comments are confined to points of practical interest essential to decisions on the suitability of pregnant phthisical patients for thoracoplasty.

In the first instance valid recommendations for this form of treatment cannot be made without careful consideration of the broad fundamental principles involved. Such are the individual variations of pregnancy and tuberculosis, for example, that attempts to formulate infallible guides to treatment are futile. In effect, an individualistic attitude must be adopted, with factors physical, psychic, economic, and sociologic in nature being most meticulously evaluated. Furthermore, in all eventualities, and because of the issues at stake, the patient, the husband, and if necessary, the relatives must be told frankly and unequivocally of the magnitude of the risks run. Moreover, the important part played by experienced nursing personnel, and the availability of suitable equipment for the effective application of this highly specialized form of treatment are not to be ignored. In addition, and because of the contingencies consequent on the combined conditions, it is desirable that the medical and obstetric supervision of these patients should be the dual responsibility of the consultant in tuberculosis and obstetrics, respectively.

Finally, it should not be necessary to stress the importance of a comprehensive after-care scheme in which help, financially or in kind, is envisaged.

In this present study, estimation of the patient's suitability for this operation, from the clinical aspect, was based on (1) the age of the patient, (2) cardiocirculatory function, (3) period of gestation, with the optimal time for the operation, in the writer's opinion, being the intermenstrual period, (4) the dominantly fibrotic character and extent of the associated lung lesion, (5) the failure of previous collapse therapeutic measures to achieve cavity closure, and finally, (6) the mental make-up of the patient.

Cognizant of the obvious dangers, immediate and remote, associated with the performance of this major operation during pregnancy, and also the fact that obstetric problems may supervene at any time to complicate the issue, the question as to whether thoracoplasty in the pregnant patient is worth while presents itself. It is submitted that in view of the grave potentialities of cavernous lung disease with positive sputum to the community, in general, the patient and offspring, in particular, thoracoplasty during pregnancy, a principle of prevention, no less than cure, might well be further exploited.

SUMMARY

Three instances are recorded in which partial thoracoplasty was performed during pregnancy. All made uneventful recoveries with sputum conversion. Furthermore, pregnancy, parturition, and the puerperium progressed with no apparent difficulty. Despite the reduction in total lung volume, dyspnea was never troublesome. Mother and child were examined at intervals, varying from three months to one year, after delivery. In each instance, both were alive and well.

Acknowledgments.—The author wishes to express his thanks to Dr. M. A. Foulis, Superintendent, Robroyston Hospital, Glasgow, who performed the operations and also to Dr. W. C. Armstrong, consultant obstetrician, Robroyston Hospital, Glasgow, for his expert management of the confinements.

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AN APPARATUS FOR ANESTHESIA IN EXPERIMENTAL THORACIC SURGERY

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THE apparatus here described has for some years provided satisfactory anesthesia for thoracic surgery in the Surgical Hunterian Laboratory of the Johns Hopkins Medical School. Numerous requests for details of its construction have occasioned this description.

The apparatus consists essentially of a motor-driven valve which periodically interrupts a stream of air or oxygen passing over an ether reservoir into an endotracheal tube. This provides alternate inflation and deflation of the lungs. An over-all view of the aparatus is seen in Fig. 1.

By means of a rheostat* the motor† may be regulated so that the interrupter valve turns at any rate up to 45 times a minute. A rate of 20 revolutions per minute is usually proper, although higher speeds may be necessary for animals weighing 20 kilograms or more. Compressed air or oxygen enters the valve at *6* (Fig. 1) and emerges through *7* to inflate the lungs. As the valve rotates to allow deflation of the lungs through an exhaust opening, it momentarily blocks the air intake at *6*, leading to increased pressure in the system proximal to this point. Compensation for this increased pressure is provided by the expansion of approximately eight feet of medium-walled rubber tubing as well as by compression of the vapor over the ether: if the flow of air is excessive or the tubing nonexpansile, one of the connections may separate. A needle valve at the air source provides control of pulmonary expansion after the thorax has been entered. A safety valve may be interpolated in the air line to prevent overdistention of the lungs, but with ordinary care in adjusting the flow of air this precaution is unnecessary. A diagram of the apparatus is seen in Fig. 2. The detailed sketch of the interrupter valve in Fig. 3 should be self-explanatory to a competent machinist.

The ether reservoir is a Wolfe bottle of one liter capacity. It operates best when about two-thirds full. The glass T tubes extend just through the rubber stoppers which are taped firmly in place. Ether is added through the central opening.

The concentration of ether in the anesthetic mixture may be varied by application of clamps to the tubing surrounding the ether reservoir, as follows (see Figs. 1 and 2):

Clamp at *10*	Negligible anesthetic effect
No clamps	Usual maintenance level
Clamp at *8* (Fig. 1)	Fairly heavy ether vapor
Clamps at *8* and *9*	Maximal anesthetic effect

With clamps at *10* and *11* there would be no delivery of ether vapor, but a clamp at *11* is inadvisable since it obviates the cushioning effect of the compressible air over the ether. Elimination of such an expansion chamber in the system may lead to respiratory difficulty or to separation of connections proximal to the clamps.

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Received for publication May 16, 1949.

*All metal power rheostat, type PR-50 (50 watts, 500 ohms). Made by International Resistance Company, Philadelphia, Pa.

†A speed-reducer motor, type NSE (11 R, 115 volts, A.C. or D.C.). Made by Bodine Electric Company, Chicago, Ill.

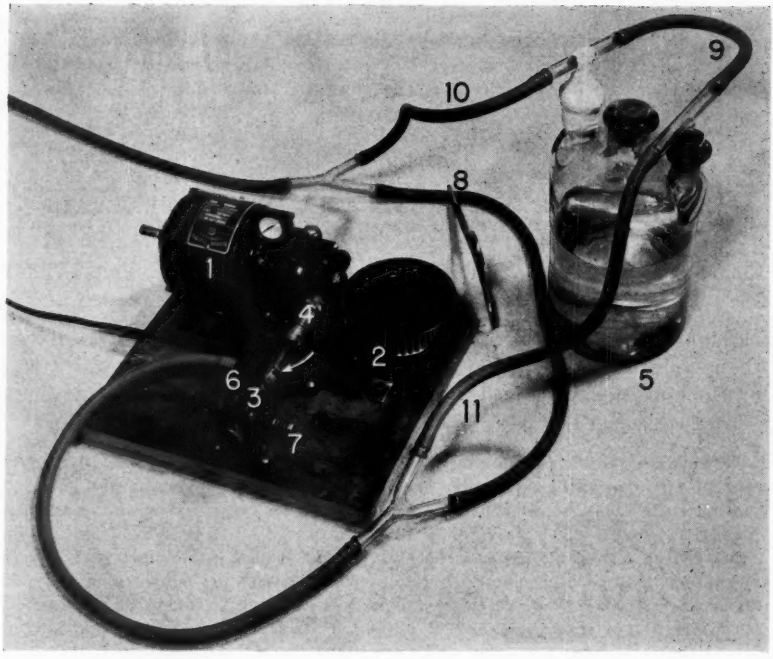

Fig. 1.—Photograph of apparatus showing motor (*1*), rheostat (*2*), and interrupter valve (*3*) connected to motor by means of a flexible coupling (*4*). Air or oxygen is blown over ether in the Wolfe bottle (*5*) to enter the valve at (*6*) and emerge from (*7*) to enter the tubing leading to the endotracheal catheter. Delivery of ether vapor may be regulated by clamps (*8*), (*9*), and (*10*). During expiration the gases are exhaled through the exhaust opening in the valve, marked by the arrow.

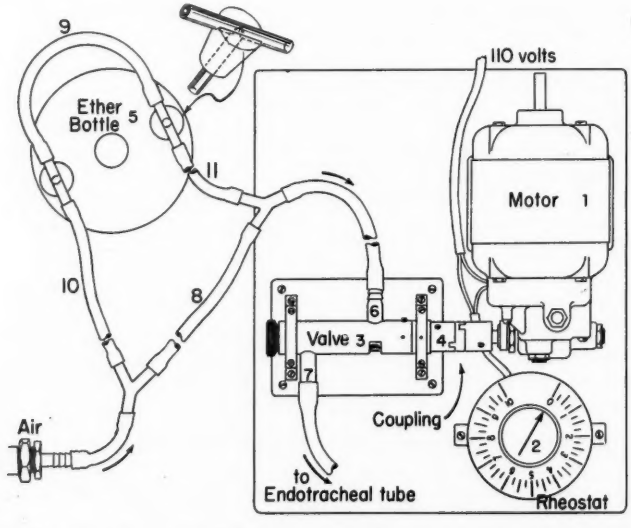

Fig. 2.—Diagram of apparatus. The numbers correspond to those in Fig. 1. (In place of the flexible coupling [*4*] shown here, one may use a "Multijaw Coupling," type FA 75, made by the Boston Gear Works, Inc., 14 Hayward St., North Quincy 71, Mass.)

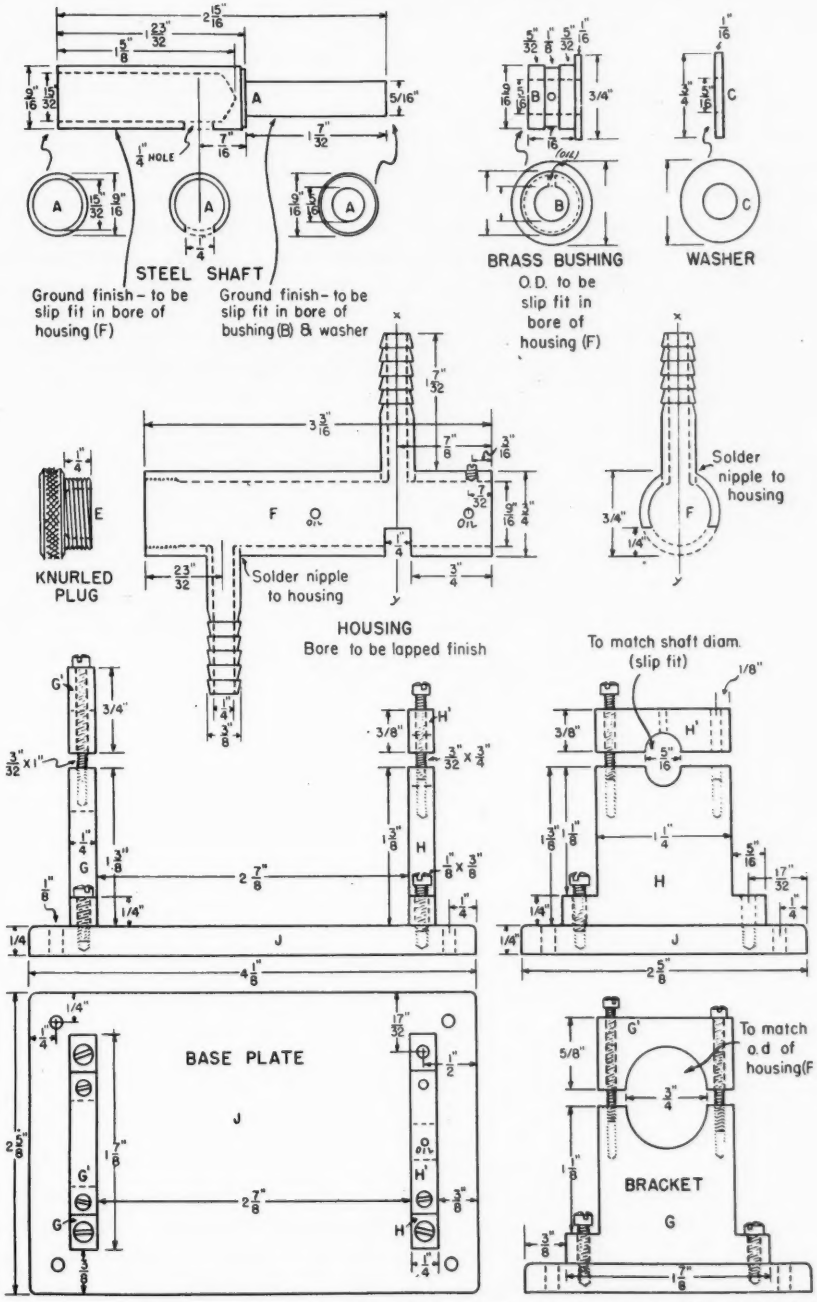
STEEL SHAFT
Ground finish – to be slip fit in bore of housing (F)
Ground finish – to be slip fit in bore of bushing (B) & washer
BRASS BUSHING
O.D. to be slip fit in bore of housing (F)
WASHER
KNURLED PLUG
Solder nipple to housing
HOUSING
Bore to be lapped finish
Solder nipple to housing
To match shaft diam. (slip fit)
BASE PLATE
BRACKET
To match o.d of housing(F

Fig. 3.—Working drawing of the interrupter valve. All parts are brass except for the central cylinder which is steel.

DISCUSSION

Our usual anesthetic practice consists of induction by open ether for a few minutes, followed by introduction of an endotracheal catheter with an inflatable cuff. When the cuff is inflated, the respiratory exchange is carried on exclusively through the catheter. A convenient length of rubber tubing connects the catheter to the apparatus, which has been previously adjusted to a proper rate, air pressure, and concentration of ether. The respiratory rhythm is soon controlled by the machine, and the only subsequent adjustments involve shifting of clamps on the tubing to vary the depth of anesthesia. It may be necessary to add ether during prolonged procedures. At the completion of operation the catheter is disconnected from the apparatus to allow resumption of normal respirations before removal of the endotracheal tube. Spontaneous breathing is resumed usually in a minute or less. The machine provides satisfactory anesthesia in dogs, cats, or monkeys.

STREPTOMYCIN PLUS ALKALINIZATION OF THE PLEURAL CAVITY IN THE TREATMENT OF TUBERCULOUS EMPYEMA

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WITH the advent of streptomycin to the therapeutic arsenal against tuberculosis[30, 31] many hopes arose that it would be a great help in the management of tuberculous empyema. Indeed, the gratifying results obtained with this antibiotic in other localizations of tuberculosis, the advantages of penicillin in the local treatment of nontuberculous empyema (associated, of course, with sound principles of surgical drainage) made it reasonable to expect similar good results with streptomycin in tuberculous empyema. Disappointment and disillusion came with early reports; with the exception of Dobric, Albertal, and Rodríguez Olivares,[2] it is a unanimous opinion that streptomycin is of little or no value at all in the treatment of tuberculous empyema.[3, 4, 5, 9, 14, 15, 18, 19, 29, 34]

Such feelings are expressed by the Statements of the Committee on Therapy and Sub-Committee on Streptomycin of the American Trudeau Society: "Streptomycin therapy is not recommended for treatment of chronic empyema of tuberculous origin, because of its apparent ineffectiveness in studies thus far reported;"[5] and by the last of the Reports to the Council on Pharmacy and Chemistry of the American Medical Association: "Chances for the successful control of tuberculous empyema with streptomycin therapy would appear to be exceedingly remote."[4]

Why has Streptomycin been ineffective so far, in the control of tuberculous empyema?

There are two pharmacologic and bacteriologic facts of extreme importance: First, streptomycin action is inhibited by an acid medium.[1, 7, 8, 16, 18, 19, 20, 26, 27, 28, 31, 35] Second, tuberculous empyema has an acid reaction as has been proved by several investigators.[10, 13, 14, 19, 33]

Neglect of those facts account, in our opinion, for the failures so far obtained, for nobody has reported attempts to reverse the acid reaction of tuberculous empyema during streptomycin therapy. Furthermore, in 1939, Canova and Agnello[10] found out that if the empyema gets worse its pH goes down; but on the contrary, improvement of the empyema is paralleled by a tendency to alkalinization of the pus. According to Trossarelli[33] in 1933, a pleural fluid with a pH above 8.1 inhibits the growth of tubercle bacilli in artificial media. These facts are of capital importance; the present treatment described by us has its foundations on them, associating, of course, sound principles of surgery for evacuation of the purulent material.

But there is another important factor in handling empyemas: bronchopleural fistulas. Coryllos,[11] Auerbach,[6] and Ornstein and Ulmar[22] have explained the pathogenesis of tuberculous empyema in the course of intrapleural pneumo-

From the Chest Service of the Instituto Mexicano del Seguro Social.
Received for publication June 6, 1949.

thorax by the occurrence of bronchopleural fistulas. Their works are widely known and need no further comment. For correction of fistulas, parenteral administration of streptomycin is the logical step; closure of fistula and sterilization of caseous foci ruptured into the pleura can be accomplished, provided that (a) the fistula be recent, small, and with no fibrotic mouth, and (b) the affected lung be maintained collapsed during the treatment.

With the preceding considerations as a basis, an original technique for the treatment of tuberculous empyema has been developed; we have employed it since December, 1947.

TECHNIQUE

For evacuation of the pus by pleural tapping, we prefer an anterior approach, high up, through the first or second intercostal space at the level of the middle clavicular line, with a fine trocar, sufficiently long to reach the posterior wall of the chest and having the patient in dorsal decubitus with slight Trendelenburg position. By proceeding in this fashion, total evacuation of the pus can be accomplished, for the tip of the trocar reaches the bottom of the fluid; the trocar tract is not continuously bathed by pus afterward, so chances of fistulization are greatly diminished. All this, of course, is when there is an intrapleural or extrapleural pneumothorax space as there has been with all our cases. After local anesthesia of the skin and intercostal space is established with 1 per cent Novocain solution, a long trocar, No. 16, is inserted into the pleural cavity, the sharp portion is withdrawn, and the cannula gently pushed until it reaches the posterior wall of the chest. Aspiration of the pus is done with a syringe. When the cavity is empty, a pleural lavage with generous amounts of normal saline is done until the fluid comes back completely clear. Then, ½ to 1 Gm. of streptomycin dissolved in 15 c.c. of 25 per cent sodium citrate solution is injected into the pleural cavity and the cannula is taken out.* If there is mixed infection (as there was in 5 cases), 100,000 to 200,000 units of penicillin are introduced along with the streptomycin-sodium citrate solution; the associated germs disappeared very soon, even in cases of putridity (2 cases).

To promote healing of fresh, soft, small bronchopleural fistulas and to sterilize caseous foci ruptured into the pleural cavity, parenteral streptomycin is administered along with the local treatment; we have employed low doses of 0.50 Gm. every twenty-four hours. Pleural permeability to streptomycin persists even in cases of thick pleura.[17, 32, 36]

Collapse therapy is maintained until total disappearance or improvement of the empyema occurs. Then if it is considered helpful for the parenchymal disease, it is prolonged and maintained; or it is changed or discontinued according to the status of the pulmonary lesions.

MATERIAL

The material herein presented consists of 35 patients of both sexes, all adults, afflicted with tuberculous empyema; all under collapse therapy; the fluid was frank pus in all cases and Koch bacilli were found by direct examination in every instance. The age of the empyemas ranged from one to three months except in 1 case, 5 months old with wide, open, rigid bronchoextrapleural fistula.

Twenty empyemas developed during intrapleural pneumothorax therapy and 15 arose as complications of extrapleural pneumothorax. Bronchial fistulas were demonstrated in 15 patients; 12 were bronchointrapleural fistulas (B.I.F.)

*At the present time we are using a buffer solution with a high pH, to dissolve the streptomycin for local instillation. The pleural lavage is done also with strong alkaline solution in order to reverse the pH of the pleural cavity quicker.

and 3 were bronchoextrapleural fistulas (B.E.F.). Three patients had cutaneous-extrapleural fistulas (C.E.F.).

DEFINITION OF CRITERIA

Complete cure of the empyema is considered here when there was total disappearance of fluid, when the cavity became sterile and bronchial fistula was demonstrable no more. Improvement of the empyema is accepted when at the end of the treatment fluid in small amount is still present, but it must be serous in character and negative for acid-fast bacilli in repeated examinations; patients with dry, sterile cavity but in whom a fistula is still present at the end of the treatment are considered as improved. The empyema is labeled unimproved when Koch bacilli are still present in the fluid at direct examination, no matter if there is general improvement and the fluid changes in physical characteristics; cases with purulent, sterile fluid are considered as unimproved.

Criteria for improvement and unimprovement might seem rather severe, but any new procedure or technique must be tested rigidly.

If parenchymal lesions are under satisfactory control by pneumothorax, but not completely arrested, the pneumothorax is maintained. In those with arrested lesions, the lung is allowed to re-expand. When the pneumothorax is doing no good for the pulmonary lesions, the program and form of collapse therapy is changed after healing or improvement of the empyema takes place. Patients in whom bronchial fistula is still present after streptomycin therapy will be submitted to surgical treatment.

RESULTS

Cured (23 patients).—Complete sterilization of the cavity and total disappearance of fluid was accomplished in all. Ten had extrapleural empyemas and 13 intrapleural empyemas. Two had B.E.F., 9 B.I.F., and 1 C.E.F., all proved at the onset of treatment; all were closed at the end.

Improved (10 patients).—In 8, a small amount of serous fluid, negative for acid-fast bacilli, was still present at the end of treatment; in fact, they are residual sterile exudates. The other 2 patients, both have their cavities completly dry and negative, but treatment failed to close their bronchial fistulas; 1 is B.E.F. and the other is B.I.F.

Unimproved (2 patients).—Both had fluid at the end of the treatment. One of them has a persistent cutaneous-extrapleural fistula provoked by repeated tappings at the most dependent site of the empyema, done elsewhere; this patient still has purulent fluid but negative for acid-fast bacilli. The other

TABLE I

		NUMBER OF PATIENTS	PER CENT
Cured		23	65.7
Improved		10	28.6
Unimproved		2	5.7
Worse and deaths		0	0.0
Total	Good results		94.3
	Unchanged		5.7

is a patient with silicotuberculosis; intrapleural pneumothorax was performed on him in order to stop repeated massive hemoptysis; so far, the pneumothorax has accomplished its hemostatic purpose but has failed to control the lung lesions; this patient still has some fluid in his pleural cavity, serous in character and positive for acid-fast bacilli.

TABLE II. FORMS OF COLLAPSE DURING AND AFTER TREATMENT

	NUMBER OF PATIENTS	
Pneumothorax maintained	22	
		13 Intrapleural
		9 Extrapleural
Changed to oleothorax	6	
		3 Intrapleural
		3 Extrapleural
Lung purposely re-expanded	3	
		Arrested lesions
Waiting for other procedures	4	

Table II shows the type of collapse during treatment and its outcome. The status of pulmonary lesions is the crux of such a matter. In 22 cases it was considered advisable to maintain the pneumothorax space because it was exerting beneficial influence upon the lung lesions, although this was not yet totally arrested. Thirteen of such patients have intrapleural pneumothorax and 9 have extrapleural ones; 17 have their empyemas cured and in 5 they are improved.

Six patients were changed to oleothorax (3 intrapleural and 3 extrapleural); in all of them it was considered necessary to maintain the collapse, but all showed a tendency to develop symphysis after treatment of the empyema; in order to maintain the efficient space, mineral oil was used, only as an antisymphysiary measure. Five have their empyemas cured and 1 improved.

In 3 patients the lung was allowed to re-expand after healing of the empyema occurred. All had long-standing collapse with arrested pulmonary lesions; all have been under control for more than five months and their status is quite satisfactory for both pleural and pulmonary status.

There are 4 patients waiting for other procedures to be done. Two patients are improved and have patent fistulas, on them, thoracoplasty will be done. Two other patients are unimproved ones: one has a cutaneous-extrapleural fistula and the other is a silicotuberculosis patient. On the first, direct surgical attack upon the fistula is being planned; on the other, we are perplexed about what to do, for we are completely pessimistic about the outlook for any form of collapse therapy on silicotuberculosis patients.

TABLE III. INFLUENCE OF THE TREATMENT ON FISTULAS

	BEFORE TREATMENT	AFTER TREATMENT	
	PATENT	CLOSED	OPEN
Bronchointrapleural	12	11	1
Bronchoextrapleural	3	2	1
Cutaneous-extrapleural	3	2	1
Total	18 (100%)	15 (83%)	3 (17%)

Table III shows results according to closure of fistulas. We believe that most cases of tuberculous empyema developed during intrapleural pneumothorax are due to bronchopleural fistulas and discharge of caseous material inside of the pleural cavity. This is not quite as universal for extrapleural pneumothorax complicated with empyemas. As tests for the demonstration of bronchial fistulas, injection of methylene blue and mint essence as well as careful recordings of manometric pressure on pleural cavity were done. This last one gave in our hands the most consistent results. Unfortunately, we did not perform gasometric studies which comprise the best method.

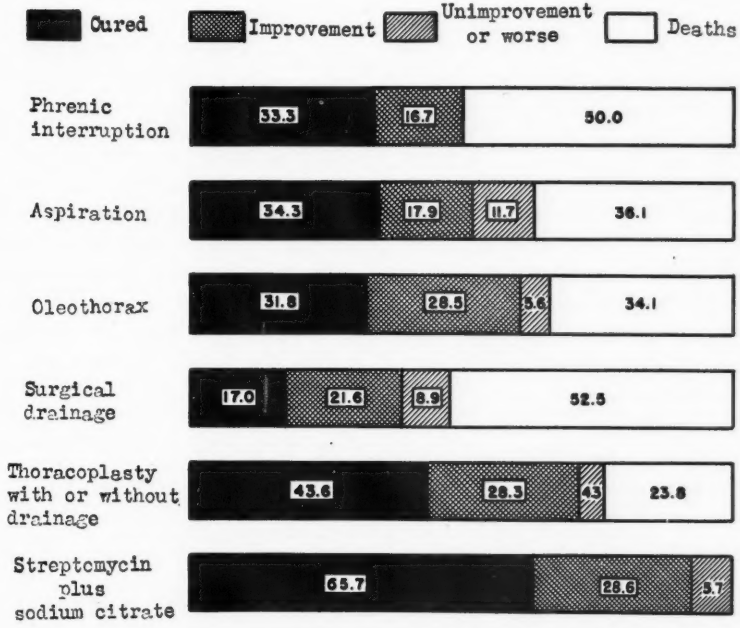

Fig. 1.—Comparative results. The percentages, except the streptomycin figures, were collected by Ehler[13] in a review of the cases reported from 1930 to 1941 by Hedblom, Jones, and Alexander, Skavlem, Woodruf, Berry, Dumarest, and Rougy, Peters and associates, Sayago and Lastra, etc.

Bronchial fistulas were demonstrable in 15 instances; 12 were B.I.F. and 3 B.E.F. Thirteen bronchial fistulas were closed at the end of treatment; 11 were B.I.F. and 2 B.E.F. Important facts for success are: age of the fistula and pathologic status of the opening. The 2 patients (1 B.I.F. and 1 B.E.F.) on whom treatment failed to close the fistulas had wide open fibrotic, old bronchial mouths. There were 3 cases of extrapleural-cutaneous fistulas. All reached us with their tracts already established; 1 carrying tube drainage and the other 2 with fistulized needle tracts, for they had been tapped several times elsewhere, at the most dependent place of the empyema. Two tracts closed spontaneously when the empyema disappeared and 1 is still open (Fig. 1).

DISCUSSION

Since December, 1947, when we began to employ the treatment herein described, we have finished treatment in 25 cases of tuberculous empyemas. All had purulent fluid, positive for acid-fast bacilli. Most of them reached us with their empyemas already established and were kindly sent by other colleagues who knew our interest in the subject. Presence of fistulas was routinely investigated by intrapleural instillations of methylene blue and mint essence and by manometric studies of pressures of the empyema cavity. Gasometric studies were not done. We believe that the real number of fistulas was, in fact, greater, but many were too small, of valvular action, intermittently open, and not detectable by the methods employed by us. Ninety-one and seven-tenths per cent of B.I.F. were closed at the end of the treatment and 4 out of 6 B.E.F. and C.E.F. were closed, too (66.7 per cent). The frequency of aspirations varied widely and was regulated by the reproduction of the fluid; usually they were made with intervals of from four to ten days. We prefer by far to make repeated aspirations over the use of tube drainage on the most dependent site of the empyema, in order to obtain better control of the pneumothorax when it is indicated to maintain it and to avoid chest wall fistulas, as it was with one of our patients who came to us carrying his tube. Performing the aspirations through an anterior approach, high up, in the first or second intercostal space, far away from regions continuously bathed by recurrent pus, minimizes the risk of a chest wall fistulization by repeated tapping at the most dependent site of the empyema; we have 2 of such patients who came to us with fistulized needle tracts.

Our technique has its foundations in:

1. Sound bacteriologic and pharmacologic principles:
   (a) Streptomycin action is inhibited by an acid medium.
   (b) Tuberculous empyema has an acid reaction.
   (c) Pleural fluid with pH above 8.1 inhibits growth of Koch bacilli.

Therefore, alkalinization of the pleural cavity must be done to create a favorable medium for streptomycin action and to make difficult the growth of Koch bacilli. This is accomplished by instillation of 25 per cent sodium citrate solution plus streptomycin into the pleural cavity*

2. Pathologic facts: The pathogenesis of tuberculous empyema during intrapleural pneumothorax and sometimes during extrapleural pneumothorax is due to a bronchial fistula and discharge of caseous material inside the cavity. Early local attack and parenteral streptomycin before irreversible fibrosis has taken place are the logical steps for correction of this condition. Failure to close bronchial fistulas in this series is due to old fibrotic openings.

*The important principle of alkalinization of the medium plus local streptomycin will have wider applications for the treatment of other forms of tuberculosis. Endobronchial segmental instillations of streptomycin plus sodium citrate solution into giant cavities of tuberculous origin, located at the posterior basal segment are being done by Dr. Quijano-Pitman[25] in 2 cases with quite satisfactory results, to improve the cavity bronchus condition. Of course, collapse therapy will be associated when the local condition will permit it. Dr. Quijano-Pitman also has injected transparietally this solution into a giant cavity located on the posterior segment of the right upper lobe before thoracoplasty.

3. *Ubi Pus Vacua:* The fullfillment of this old and wise principle of general surgery is observed by evacuation of the pus through a safe approach to avoid fistulization.

The beneficial influence of the treatment is reflected two ways, local and general. Locally, the fluid thins out, becomes serous, the amount decreases, its reaction reverses to alkaline, and Koch bacilli disappear soon. The general gain parallels local improvement: fever subsides, patient gets appetite and strength, and weight improves. There were no signs of intolerance for the streptomycin and no patient became worse or died in the present series.

The excellent results obtained by this method can be compared with advantage with other types of treatment for tuberculous empyema (see Fig. 1). Among 35 patients, 23 were cured (65.7 per cent). Ten patients were improved (28.6 per cent); in eight of them, the effusion is not a problem anymore; 2 other patients still have bronchial fistulas, but sterile, empty empyema cavities. It can be fairly said that in 94.3 per cent of the patients good results were obtained. This is in a very sharp contrast with the results of streptomycin therapy of tuberculous empyema obtained by the group of veterans hospitals as it was reported to the Council of Pharmacy and Chemistry of the American Medical Association;[4] they reported 35 cases, too, and 22 of them were considered as unimproved (61.4 per cent). In their report, there is no mention of alkalinization of the pleural cavity.

SUMMARY

Failure of streptomycin for the treatment of tuberculous empyema is generally recognized. The causes of this failure are discussed. Four factors have capital importance:

1. Streptomycin action is inhibited by an acid medium.
2. Tuberculous empyema exudate has an acid reaction.
3. A high pH inhibits proliferation of Koch bacilli in pleural fluid.
4. Early parenteral streptomycin therapy may help to heal fresh, soft, small fistulas.

An original technique for treatment of tuberculous empyema is presented. This technique is based on the following: Alkalinization of the pleural cavity plus local instillation of streptomycin. Frequent removal of pus performed by pleural tapping through a high, anterior approach. Associated parenteral administration of streptomycin.

Advantages of this technique are enumerated, and results obtained in 35 cases of proved tuberculous empyema are presented.

The technique described gives better results than any other procedure employed up to now for treatment of tuberculous empyema.

Acknowledgment.—We are very grateful to Dr. Fernando Quijano-Pitman for his valuable help in the realization of our work and his assistance in the translation of this paper, to Dr. Alberto Monnier-Millote for doing the laboratory work in our cases, and to the staff of the Unidad de Neumología y Cirugía de Torax del Instituto Mexicano del Seguro Social and other colleagues who sent us their patients with tuberculous empyema to be treated by our method.

ADDENUM

A first report, including 30 cases, was delivered in Spanish by us at the Third National Congress of Tuberculosis and Silicosis held at Mexico City in January, 1949. Shortly thereafter, at the same Congress, Professor Attilio Omodei-Zorini from the Forlanini Institute of Rome, presented a paper in which he stated that on a date posterior to the initiation of our work and without previous knowledge of it, the Italian authors began to employ a method for the treatment of tuberculous empyema based on the same principles on which our method is founded. Their technique, however, differs slightly from ours, for they use permanent closed drainage by means of a tube inserted on the most dependent place of the empyema; they perform daily lavage and instillation of streptomycin plus sodium phosphate instead of sodium citrate. Up to January, 1949, they had treated 22 cases of tuberculous empyema with quite satisfactory results.

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TRANSSCAPULAR THORACOPLASTY

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THIS subject, unorthodox division of muscles in thoracoplasty, may not be considered by many surgeons as an important or interesting one. Nevertheless, several papers have been written on it, some of them quite original, like: "Thoracoplasty Without Section of Muscles" by Finochietto and "A Musculoplastic Incision for Posterior Thoracoplasty" by Brock. Head and Wangensteen have also performed this operation through small incisions with splitting of muscles without dividing them. All these authors aimed at reducing the postoperative reaction, minimizing the impairment of shoulder movement and the amount of pain, and even bringing down the incidence of wound infection.

Wound infection in thoracoplasty operations is not so uncommon as it is generally believed. As Wangensteen said long ago, "the leaving of a 'dead space' which must fill with blood and sanguineous transudate invites infection and is admittedly in conflict with the well-established principle of obliterating all planes in which fluid may collect." According to Overholt and Betts, "the reports from the literature indicate that some degree of wound infection occurs in approximately 15 per cent of all cases." Gale and Oatway reported 18 per cent of infections in their 1936 series and only 9.5 per cent in their 1937 series. No doubt, with the great advances accomplished in thoracic surgery in the last years, the incidence of wound infection in thoracoplasty is considerably lower than it used to be.

In my paper, "Scapulectomy and Thoracoplasty," I tried to prove that infection of the extrapleural space can easily be avoided by following the advice given by Wangensteen, that is to say, by the early obliteration of that space. This can be accomplished by the resection of the lower one-half of the scapula during the first stage.

Wangensteen's advice to fill the extrapleural space with a synthetic rubber sponge coated with paraffin, like other procedures recommended for the obliteration of the "dead space" with different materials, had to be given up on account of a high incidence of failures.

In 1947 I thought that we had found the answer to extrapleural infection by the prophylactic use of penicillin-sulfathiazole powder, sprinkled over the operative area before the closure of the wound. Two cases of deep sepsis, occurring after the publication of my paper, have strengthened even further my conviction that the best and surest method of avoiding infection of the extrapleural space is by the early obliteration of the "dead space," by the apposition of the walls of this space, particularly its posterior and anterior walls. Anteriorly we know that the infraclavicular fossa will "sink" immediately after the resection of the anterior portions of the first three ribs. It is only the presence of the scapula that will keep a "dead space" over the collapsed lung.

Received for publication Aug. 18, 1949.

This short paper is based on the experience of seventy-two complete thoracoplasties without a single case of infection, either deep or superficial. In all these cases the lower one-half of the scapula was resected prior to resection of the ribs and early bedding of the remaining scapula was obtained after the first stage.

In sixty-three cases the scapula was resected through a small incision along the vertebral border of this bone. Following the resection of one-half of the scapula, it was found that the trapezius and rhomboids need only be partially divided, as the direction of the scapula retraction was toward the shoulder instead of toward the axilla when the bone is intact. The latissimus and the serratus were spared altogether. In some cases the division of trapezius and rhomboid was so limited that the operation could have been termed a "pseudo-Finochietto thoracoplasty." It is granted that the exposure was not a very "comfortable" one, but in thin patients it was quite sufficient.

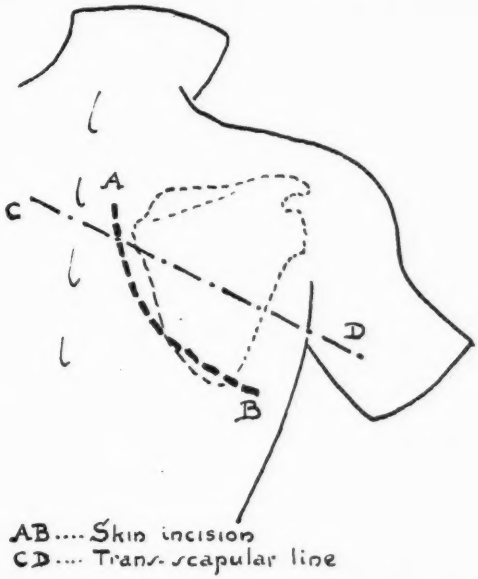


Fig. 1.

As is always the case with surgical techniques, I have found now that the rhomboid need not be divided at all, and even the trapezius can almost be spared, except for a small incision across its scapular edge, if the operation is performed through the transscapular approach that I am about to describe. As can be seen in the accompanying illustrations the technique is quite simple.

The skin incision can be a limited periscapular one, starting between the spine and the superior angle of the scapula, round this bone, to its inferior angle (Fig. 1). The skin flap overlapping the scapula is then undercut until the lower one-half of this bone is freed all over (Fig. 2). The infraspinatus is incised along

an oblique line roughly following the direction of the underlying fourth rib (Fig. 3). Through this opening the bone is freed subperiosteally. A tunnel is then made with the raspatory between the scapula and the subscapularis, wide

Fig. 2.

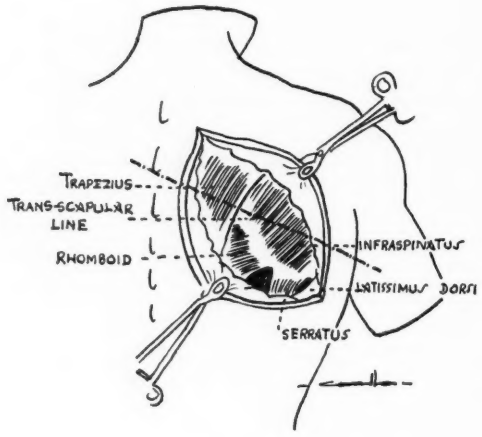
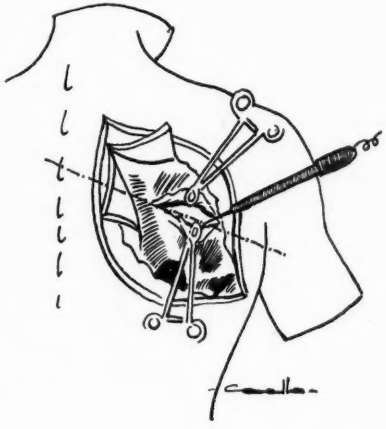


Fig. 3.



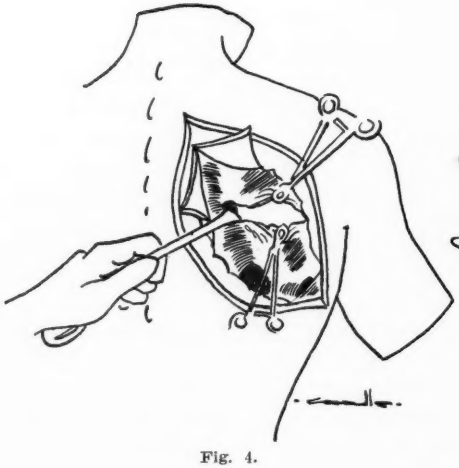


Fig. 4.

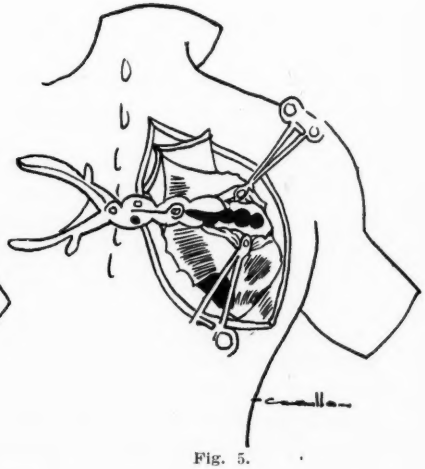


Fig. 5.

enough to allow later on its division with the bone rongeur (Fig. 4). No other bone cutter at our disposal can do this job so neatly and quickly. The bone is divided by sucessive bitings. The end bridge at the axillary border of the scapula

can be finally divided with any straight bone cutter (Fig. 5). Once loose, the lower one-half of the scapula is gripped with a bone forceps and pulled out vigorously, therefore facilitating the subperiosteal dissection of its anterior aspect

Fig. 6.

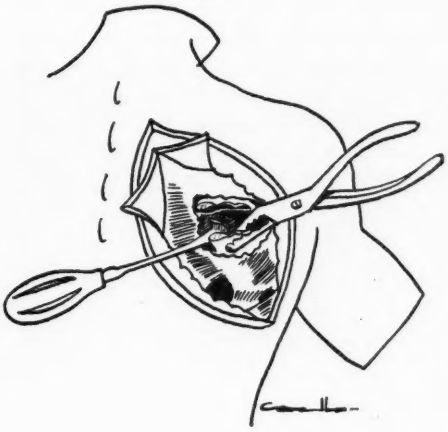


Fig. 7.

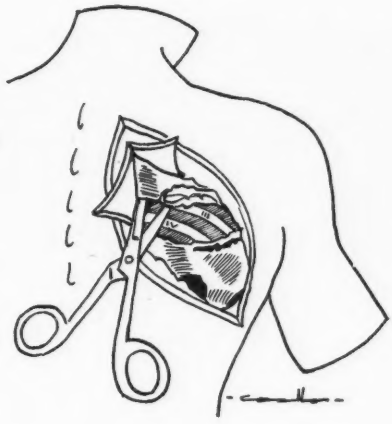


Fig. 8.

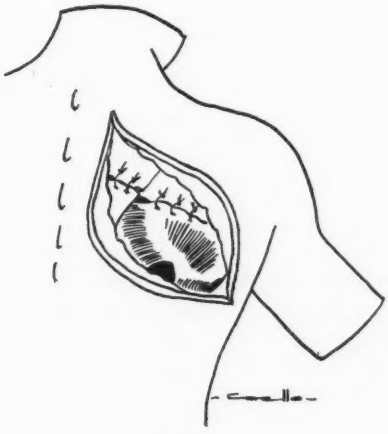


Fig. 9.

(Fig. 6). An opening is then made through the fibers of the rhomboid along a line in continuation with the transscapular incision. The tough periosteal bridge between the rhomboid and the subscapularis at this point has to be divided with

scissors (Fig. 7). The opening thus obtained is then enlarged by vigorous manual separation of its edges, upward and downward. The retraction of the remaining scapula will now be toward the shoulder, and if a self-retaining scapula retractor like the one described by Overholt is available, the operation can be performed single-handed (Fig. 8).

The division of a few fibers of the trapezius needed for this approach can be done either now or at the beginning of the operation. I usually begin by resecting a segment of the fourth rib. This is followed by complete resection of the third, second, and first ribs in that order. At the end of the operation all the stitching up that is wanted is a few stitches over the infraspinatus and trapezius as shown in Fig. 9. As the upper one-half of the scapula falls in and gets bedded into the decostalized upper chest, the result can be seen in Figs. 10, 11, and 12.

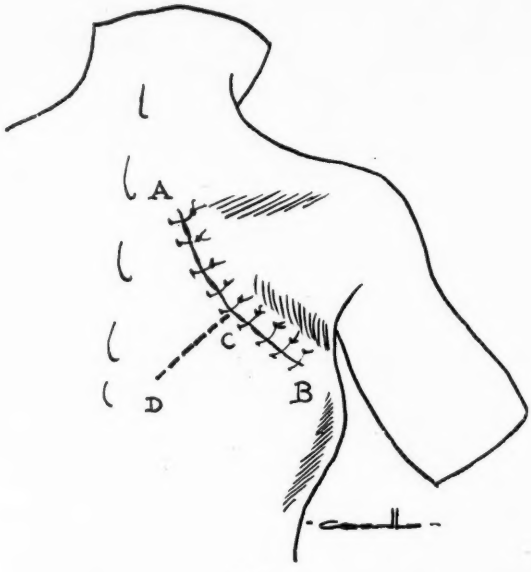


Fig. 10.

This approach may not satisfy surgeons who, quite rightly, want to operate with a "comfortable" exposure, but it is certainly adequate for those who are very concerned about making this operation as little traumatic as possible. All patients recover much more quickly than with the extensive periscapular division of muscles. For a second stage all that is needed is to reopen the old incision and extend it downward from its middle toward the spine (Fig. 10, *CD*).

SUMMARY

A new approach for an upper thoracoplasty is described by means of a transscapular incision with division of the infraspinatus and only a few fibers of the trapezius. The lower one-half of the scapula has to be resected and the

rhomboid need only be split along its fibers. The operation can be done in a short time, the amount of trauma is minimal, the postoperative recovery is very quick, and above all, it is an excellent prophylactic measure against extrapleural space infection due to the early obliteration of that space.

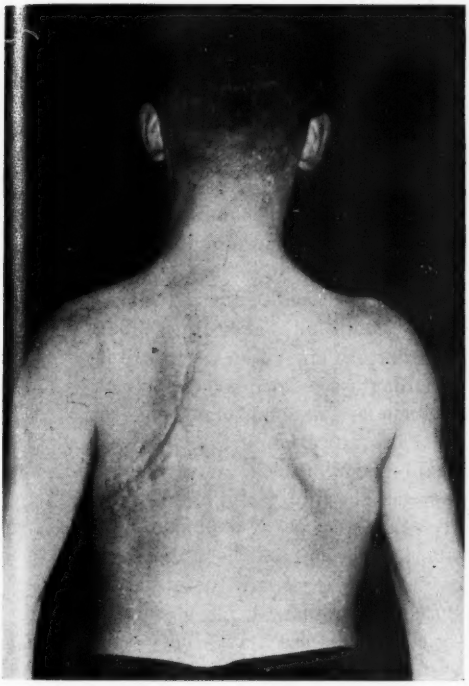


Fig. 11.

Fig. 12.

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EXPERIENCES WITH THE SURGICAL RESECTION OF THE HUMAN CARINA, TRACHEAL WALL, AND CONTRALATERAL BRONCHIAL WALL IN CASES OF RIGHT TOTAL PNEUMONECTOMY

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IT HAS been a common unfortunate experience for physicians to discover carcinoma of the right upper lobe in such an advanced stage of its existence as to be felt beyond the help of surgical attempts at cure. In an over-all survey of the literature and personal cases with carcinoma of the lung totalling 2,843 patients, approximately 50 per cent of the patients are found to have the disease beyond the confines of the involved hemithorax, and therefore are considered inoperable. Of the remaining 50 per cent of the patients, in whom exploratory thoracotomy is felt to be justified, 36 to 60 per cent of those explored are found to have the lesion still in a resectable condition. Therefore, in an over-all summary of case reports found in the literature one may expect to find from 18 to 30 per cent of the patients, in whom a diagnosis of primary carcinoma of the lung is made, to have the disease in a stage satisfactory for one to feel that total pneumonectomy is justified with hope for eradication of the disease.

The accepted explanation for this remarkably poor outlook for carcinoma of the lung is felt to be due to three main factors. The first factor is the very insidious course of carcinoma of the lung in regard to early symptomatology and its marked ability to imitate other less serious lesions in the pulmonary system. The second factor has been the delay caused by the patient, consisting of the interval from the onset of symptoms to consultation with his physician. An inadequate consciousness of the possibility of this disease by the laity may therefore be considered to exist. The third and final factor has been the delay consequent to the physician, from the time of patient consultation to the making of a probable or positive diagnosis of carcinoma.

Certain new technical advances toward earlier positive diagnosis have recently appeared. These consist of (1) the study of the sputum and bronchial secretions for possible neoplastic cells, and (2) the increasing use of screening x-ray programs. As a result, these patients are being brought to the attention of the thoracic surgeon at an increasingly earlier stage of their disease. Certainly this has been true of lesions arising in the lower lobes. However, primary carcinoma in either upper lobe is still remarkably liable to be seen in a late stage in the course of the disease. This is considered to be due to two fundamental factors, namely, the marked tendency to consider an upper lobe carcinoma to be a tuberculous lesion, and an apparent tendency for upper lobe lesions to become symptom-producing at a later stage in the disease than that which is seen with lower lobe tumors.

From the Emory University School of Medicine, Department of Surgery (Thoracic).
Read (by title) at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

It is seldom that one encounters marked symptoms from carcinoma of the lung until secondary infection has intervened. It appears that there is a decreased liability to early infection in tumors arising in the upper lobe areas. When a study is made of the localization of primary carcinoma, it is found that from 40 to 45 per cent of the lesions arise in an upper lobe. In a recent study made in our clinic of 112 primary carcinomas of the lung 51 of the lesions were found to arise in an upper lobe.

Fig. 1 signifies the proportion of patients found to deserve exploratory thoracotomy and the percentage of those justifying resection, in an over-all total of 2,731 patients derived from reports from the literature. The second, and similar column, signifies the same factors in 112 personal cases.

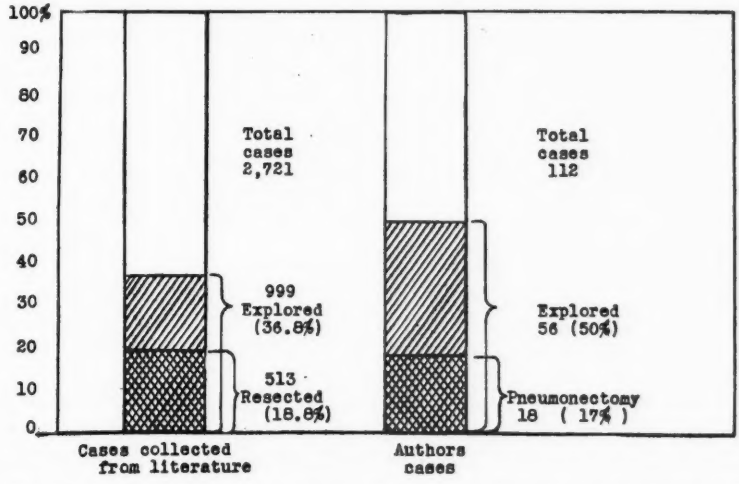


Fig. 1.—Graphic representation showing the existing frequency of inoperable primary pulmonary carcinomas. Incidence of explorations and operability in series from literature and from this series.

Fig. 2 is presented to show the localization of the primary site of the tumor in the 112 patients which the author has described elsewhere.[1] Our experience has been very similar to that of other investigators in that approximately 50 per cent of the patients in whom a diagnosis of carcinoma is made are found to be in an inoperable condition. In both our experience at Emory University and a study of the figures made at the Barnes Hospital, St. Louis,[2] we have found

Right upper lobe	30	Left upper lobe	21
Right middle lobe	4	Lingula	3
Right lower lobe	23	Left lower lobe	21
Right apex	4	Left apex	2
Right peripheral	6	Left peripheral	6
Total	67	Total	53

Fig. 2.—This chart records the localization of the primary neoplasm in 112 proved cases of primary pulmonary carcinoma. Particular stress is placed upon the primary lesion arising in the upper lobes in 54 of the total cases, or 42.8 per cent.

the highest proportion of inoperable cases to consist of patients with upper lobe lesions. Thus, inoperable lesions were considered present in from 70 to 80 per cent of upper lobe tumors.

A further subdivision of these lesions has shown an even greater tendency for lesions arising in the right upper lobe to present themselves in an inoperable condition. The apparent reason for this higher inoperable tendency has been considered due to two main causes, namely, the proximity of the superior vena cava to the primary lesion, as well as the frequency with which right upper lobe lesions travel upward along the right lateral tracheal wall, and/or involve the carina and medial wall of the contralateral bronchus.

Claggett and his co-workers[3] presented a very detailed and valuable study showing the marked tendency for bronchiogenic carcinoma to travel in a cephalad direction along the trachea and bronchus. He has suggested that one should obtain from 1.5 to 2.5 cm. of uninvolved bronchus proximal to a tumor if one is to hope to achieve eradication of this lesion.

The marked variance for the site of origin of the right upper lobe orifice has received considerable comment. Although the average normal position is described as 2.5 cm. below the carina, a much higher point of origin is frequently seen and occasionally the orifice may arise from the lateral wall of the trachea itself. Therefore, in view of the variable sites of origin of the right upper lobe orifice, as well as the marked tendency for lesions arising in the upper lobe to present involvement of the trachea or carina at the time of definitive diagnosis, it is considered that the technical considerations utilized in pneumonectomy, wherein a right upper lobe tumor is present, must of necessity differ from similar considerations wherein the primary lesion arises at a greater distance from the trachea and carina.

The purpose of this communication is to describe our personal experiences with an attempt to extend the indications for resection in right upper lobe carcinoma of the lung. Certainly one should not condone the need to have to carry out a considerably more hazardous and extensive resection, and the primary purpose of the men interested in this subject should be made toward an earlier diagnosis of the lesion before this type of complication is presented. Nevertheless, it is felt that there will be certain patients, even in the presence of an early diagnosis, in whom the position of the primary tumor will require the excision of tracheal wall, carina, and contralateral bronchial wall in order to obtain an adequate margin of healthy tissue beyond the primary lesion. The author also feels that the method which is to be presented will, in all probability, be discarded as the fundamental experimental work of Daniel[4] achieves a safe application to the human being. However, in our experiences with this method, we have also encountered certain interesting physiologic and physiopathologic clinical observations which are felt to be worthy of report.

One frequently encounters statements in the literature indicating a fear on the part of the operating surgeon of the danger consequent to an open stump during the performance of total pneumonectomy. In a recent article by Strieter,[5] in discussing the value of intracardiac adrenalin in cardiac resuscitation, this concept was again stressed. In our clinic we do not

have a similar concept of the potential danger of a large open area in the stump of the main-stem bronchus or even in the presence of a large area of excision of the lateral wall of the trachea and carinal region. It is our interpretation, based upon the fundamental concepts portrayed by the empyema commission,[6] that adequate aeration of the remaining lung may be obtained as long as two factors are considered, namely, the maintenance of the mediastinal structures in their midline position, and the obtaining by the remaining lung of adequate amounts of oxygen.

It has been the policy of our clinic to support the mediastinum by traction sutures either in the wall of the involved bronchial stump, the trachea, or surrounding mediastinal structures whenever an open bronchial stump is produced. Emphasis is placed upon adequate suction measures in the region of the open stump, to prevent the spillage of blood or other materials into the functioning tracheobronchial tree. Furthermore, at the time during which the bronchus is opened, special suction tips are introduced to allow adequate clean-out of the tracheobronchial tree whether one is performing a pneumonectomy or a lobectomy. We have been impressed with the marked value of this procedure and its complete freedom from danger. The suction maneuver is carried out with due consideration of the removal of oxygen which is being delivered to the patient so that the actual time interval of suction is limited at all times to periods of thirty seconds.

We have also found clinical confirmation of the concept indirectly presented in this regard by the empyema commission, relative to the amount of paradoxical or disturbed respiratory function which may be permitted in relation to the patient's vital capacity. Thus, in a patient with a marked decrease in function of the contralateral lung, it may be necessary to introduce the endotracheal tube past the area of open trachea into the main bronchus. Furthermore, a patient may have a potentially high vital capacity of the remaining lung tissue markedly disturbed by aspiration of material spilled over from the resected, diseased lung tissue. Adequate aspiration through the tracheal defect will then permit withdrawal of the endotracheal tube and oxygen delivery so long as the mediastinum is supported. It should be mentioned that this operation is only performed with the patient supine. An anterolateral incision is utilized whenever tracheal or carinal region is planned or considered a possibility.

In all patients undergoing this procedure, a very marked physiologic disturbance characteristic of anoxia could be produced by relaxation of the stabilization sutures in the mediastinum prior to closure of the tracheobronchial defect. It is felt that this stabilization allows the intrapleural pressure in the left hemithorax to become adequately negative in relation to atmospheric pressure to allow adequate aeration of the left lung. As this mediastinal support is relaxed there ensues a decreasing expansion of aerating left lung with resultant progressive anoxia. In correllary fashion overdisplacement of the mediastinum toward the right will decrease the efficiency of expiration. Therefore, these stabilization sutures are retracted only to maintain the persisting portions of trachea and left main-stem bronchus directly above the dorsal vertebra. With this in mind, there is considerably less chance for these traction

sutures to be pulled through the tissues by an overzealous assistant. These sutures are removed or in some places utilized in application of the pleural graft overlying the suture line or artificial trachea. Fig. 3 demonstrates the typical placement of these stabilizing sutures. In our experience when these stabilizing sutures are properly used, there is no danger inherent upon an open major bronchial stump or huge intrathoracic opening in the tracheal wall. Furthermore, no positive pressure need be delivered into the surviving lung nor direct instillation of oxygen unless there exists a markedly lowered vital capacity in that lung.

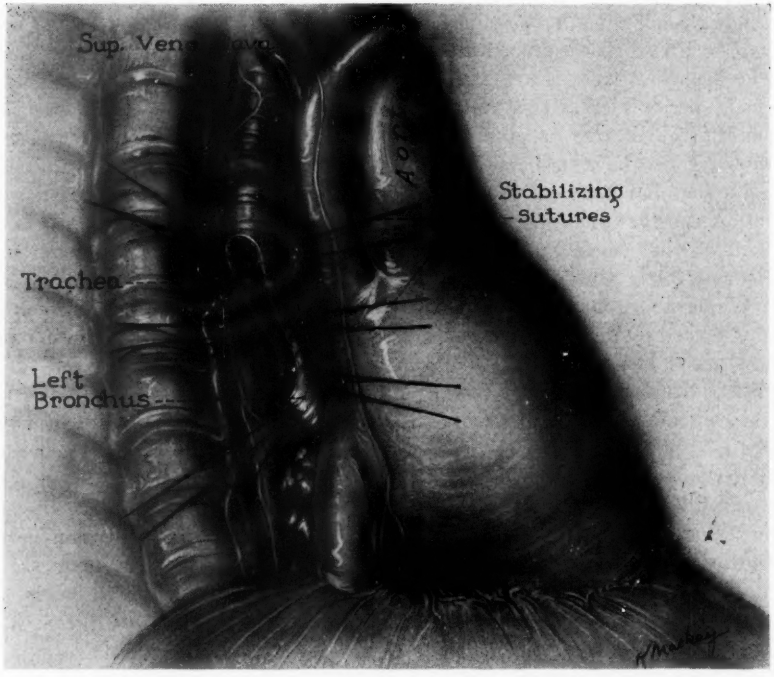


Fig. 3.—Artist's drawing demonstrating the placement of traction sutures used to stabilize the trachea and left main-stem bronchus in patients undergoing resection of these structures.

We have been sufficiently impressed with this basic concept that we have utilized it in the repair of large tracheoesophageal fistulas in newborn infants. Thus, in the newborn child in whom a large area of atelectasis and considerable soilage of the bronchial tree is presented and preoperative bronchoscopic measures are required, we support the posterior surface of the trachea prior to transsecting the area of fistulous communication. After the area of fistula has been transected, a small catheter is introduced directly into each main-stem bronchus to clean out the bronchial tree. We have found this procedure to be of a definite benefit to the patient, and apparently without associated danger.

We have adhered to the policy at the time of removal of a lung for carcinoma to obtain frozen sections upon the proximal stump of the bronchus of the resected lung. Should this reveal evidence of submucosal extension of the tumor, or direct examination of the resected specimen show that an inadequate margin of normal tissue has been removed, surrounding tracheal wall, carina, or contralateral bronchial wall is removed until such an adequate margin is felt to have been obtained.

With these principles in mind, our first patient to be considered in this discussion was encountered eleven months prior to the writing of this paper. In order to eradicate the area of disease we were left with a large oval defect extending one inch up the right lateral tracheal wall, and the carina, together with a portion of the medial wall of the left main-stem bronchus, was removed. The cartilage on the lateral wall at the juncture of the trachea and origin of the left main-stem bronchus was found to produce a marked inward projection of the wall with consequent occlusion of the airway, when the trachea was held in the midline and an increasing degree of obstruction was produced as the mediastinum was drawn toward the right side. It was obvious, therefore, that the closure of this defect by a nonrigid substance such as a large pleural graft, would be unsatisfactory. Furthermore, such a graft could be compressed toward the left lateral wall of the tracheobronchial juncture with increasing pressure produced within the right hemithorax.

It was found that by mobilization of the tissues adjacent to this area, that the basic plastic surgical principle of a transverse closure of a longitudinal wound would both enlarge the lumen of the airway as well as tend to swing the left main-stem bronchus into a more vertical position (Fig. 4). The endotracheal tube was therefore advanced downward to the left main-stem bronchus and sutures laid, in order to accomplish this repositioning, and a satisfactory closure obtained. This defect was then covered with a pleural graft and no complications were encountered until the endotracheal tube was withdrawn up into the trachea and positive pressure introduced. When this was done the mediastinum tended to move laterally toward the right thorax and evidence of obstruction was encountered. As soon as the positive pressure was released and the mediastinum allowed to resume a position slightly to the left of the midline, an adequate airway was obtained. Therefore, with these considerations, when the patient's thorax was closed a slight positive pressure was maintained within the right hemithorax. In this first patient, because of a fear of the liability toward disruption of the suture line, the right pleural cavity was evacuated of fluid and a positive pressure pneumothorax maintained.

The patient underwent an uneventful recovery but it was noted during the postoperative course, that when the mediastinum shifted toward the right side and the pneumothorax allowed to become negative in both phases, dyspnea ensued. It was necessary, therefore, to maintain constant refills during the first six weeks postoperatively, after which time an increasing interval was allowed apparently due to fixation of the mediastinal structures. However, as time progressed there was a definite undesirable tendency for the mediastinum to assume a position to the right of the midline, which could not be satisfactorily

controlled by injections of air, and finally responded to the injection of plasma into the pleural cavity. We have not as yet used any permanent foreign bodies in the right pleural cavity at the time of surgery in an attempt to counteract this difficulty.

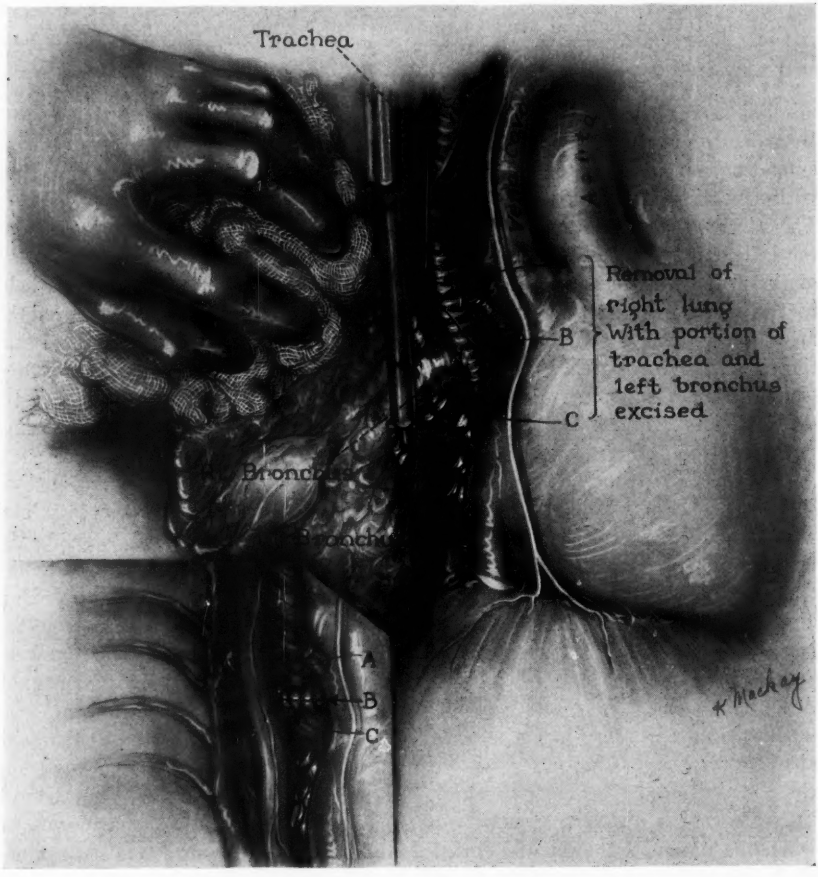


Fig. 4.—Artist's drawing illustrating the application of transverse closure of a longitudinal eliptical opening produced by partial excision right lateral tracheal wall, the carina, and upper portion left main-stem bronchus. Insert on lower left shows completed closure.

It is felt that this first patient constituted a considerably severe test case, inasmuch as there was an advanced amount of bronchiectasis in the remaining contralateral lung and the pre- and postoperative roentgenograms in this patient are presented in Figs. 5, 6, and 7.

The second patient in whom this type of operation was carried out was a 62-year-old white woman (Figs. 8 and 9). This patient's symptoms began three years prior to her first consultation in this clinic, consisting of a cough, a wheezing sensation in the right upper chest, dyspnea, and fatigability. In

July, 1946, bronchoscopy was done at another institution and endobronchial portions of the tumor removed bronchoscopically. From July, 1946 until July, 1947, this procedure was repeated on three instances due to recurrence of the original symptoms, particularly that of wheezing. She was first seen in this clinic in September, 1947, and on bronchoscopy definite tumor tissue was seen to be arising from the region of the right upper lobe and invading across the carina and upward along the right lateral wall of the trachea. The right main-stem bronchus was occluded and sufficient tumor tissue was removed to allow an

Fig. 5.

Fig. 6.

Fig. 5 (H. G.).—Roentgen film showing advanced atelectasis of right middle lobe and partial obstruction throughout remainder of right lung.

Fig. 6 (H. G.).—Lipiodol bronchogram illustrating obstructive factors in right lung and bronchiectasis in left lung.

airway. The material obtained was quite interesting inasmuch as there was a typical adenoma type of pathology throughout the majority of specimens removed, but there were additional areas of distinct transformation into a grade 3 squamous carcinoma. This happens to be the fourth instance in which localized areas of definite transformation of so-called "benign bronchial adenoma" into true carcinoma had been shown microscopically in this clinic. The patient was operated upon through a right anterior approach. Involvement of the mediastinal nodes was found to be present and a radical pneumonectomy was carried out with complete excision of the mediastinal nodes as well as the involved area of the lateral wall of the trachea, the carina, and the upper 2 cm. of the medial wall of the left main-stem bronchus. Pathologic study of the tissue removed showed adenoma type of tissue to be found in the mediastinal lymph nodes, but the actual squamous carcinoma appeared to be well confined within the substance of the lung. In this patient the size of the left main-stem bronchus would not allow the introduction of the endotracheal tube during the performance of the closure of the defect in the airway, and it

was necessary to insert a bronchoscope, which helped considerably in straightening out the axis of the tracheobronchial juncture and allowing a satisfactory closure to be performed. Again during the postoperative course it was necessary to keep the mediastinal structures slightly to the left of the midline in order to maintain an adequate airway, and some edema occurred about the suture line, requiring bronchoscopic attention for partial atelectasis of the remaining lung then shrinking agents were applied locally. Dried plasma was given intravenously in one-fourth normal dilution in an attempt to retard the

Fig. 7 (H. G.).—Postoperative roentgenogram taken two weeks after right total pneumonectomy and resection of carina with plastic repair.

formation of edema at the suture line. This was felt to be of some definite benefit in this patient. The patient progressed well and was discharged from the hospital one month following surgery. The mediastinal structures were maintained in position with pneumothorax refills. The interval between pneumothorax refill was unduly prolonged at the beginning of the third month, postoperatively, and the patient developed severe pain over the left lower anterior chest of a type and degree sufficient to make one suspicious of the possibility of coronary occlusion. This was associated with severe nausea and vomiting. No evidence of coronary occlusion could be obtained either by the cardiologist or electrocardiographic studies. On the second day following this acute episode, the patient developed an acute dilatation of the stomach, requiring institution of Wangensteen suction. Despite this procedure, the patient continued to vomit, have severe nausea, and the left lower chest pain continued. X-ray studies revealed evidence of some atelectasis in the left lower lung field, so bronchoscopy was done, and one was immediately impressed with the marked

obstruction at the juncture of the trachea and left main-stem bronchus on the left lateral wall due to considerable kinking of the trachea toward the right. A positive pressure was then instituted in the right chest by means of the injection of air. It was extremely striking to note that the patient had immediate relief from nausea, vomiting, and left lower chest pain, and marked general improvement. The patient was then allowed to return home, but difficulty in the institution of refills of the right pneumothorax were encountered by the patient's physician, with recurrence of all of the original symptoms of nausea, vomiting, gastric dilatation, and left lower chest pain. On this occasion the relief following the insertion of air into the right chest cavity was not nearly as striking as on previous occasions, and x-ray studies showed evidence of a

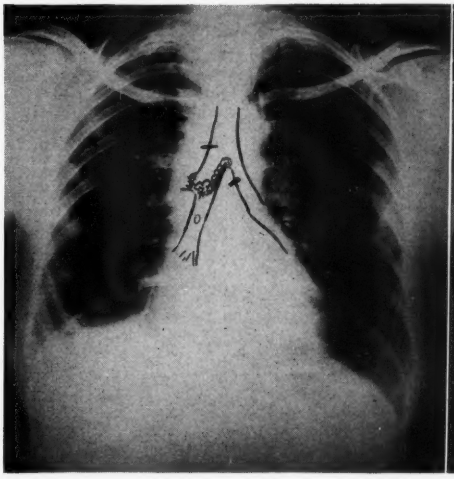


Fig. 8.

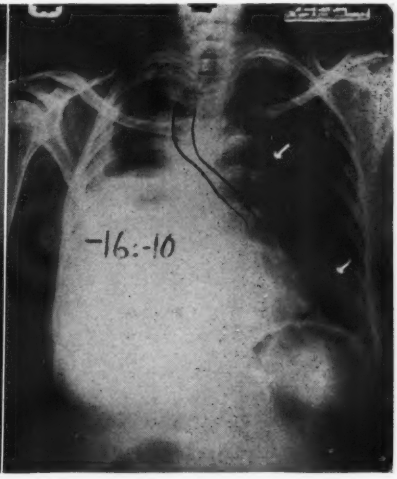


Fig. 9.

Fig. 8 (R. J.).—Preoperative x-ray study with added diagrammatic representation of tumor extension upon carina. Area resected at operation is outlined by transverse lines on right lateral tracheal wall and medial wall left main-stem bronchus.

Fig. 9 (R. J.).—Roentgenogram of chest following radical right total pneumonectomy. The course of the newly constructed airway is outlined diagrammatically, showing obstruction produced at closure site in the presence of a highly negative right intrapleural pressure.

complete obstruction at the pylorus. It had been necessary to sacrifice the right vagus nerve due to direct extension of the tumor at the original pneumonectomy. Considerable attention was paid by the radiologist to the possibility of the stomach presenting the motility pattern seen following vagotomy. This was not considered to be present on x-ray studies. However, in view of the possibility of such an atonicity, the patient was given a thorough clinical trial on Urecholine. This medicine produced no benefit in the clinical syndrome. Evidence of complete obstruction at the pylorus persisted so that exploratory laparotomy was finally indicated. However, this procedure failed to reveal any organic cause for obstruction at the pylorus, nor evidence of metastatic disease within the peritoneal cavity except for the presence of a very small nodule high up on the posterior superior surface of the liver, which tissue was

not available for direct visual examination or biopsy. A gastroenterostomy was performed, but following operation the patient persisted in marked pyloric obstruction and a nonfunctioning stoma with persistent nausea and vomiting. It was interesting to note that this nausea and vomiting persisted despite the institution of adequate Wangensteen suction. In view of this situation being noted prior to exploratory laparotomy, special attention was paid at that time to the possibility of a low "closed loop" obstruction. No evidence of any form of intestinal obstruction was discovered. It was felt necessary, therefore, to attempt to displace the mediastinum again to the left of the midline, which

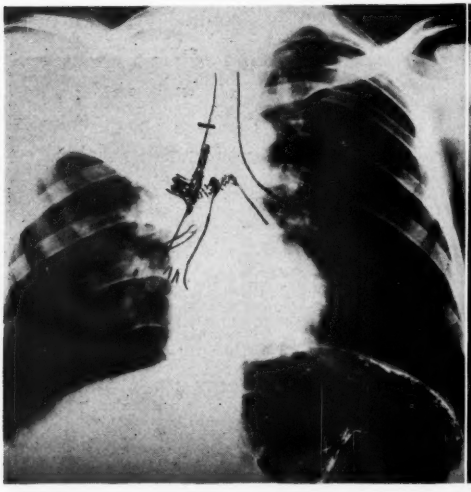


Fig. 10.

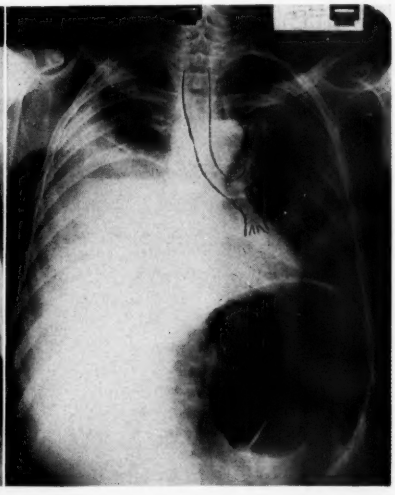


Fig. 11.

Fig. 10 (H. H.).—Posteroanterior x-ray film study showing complete atelectasis right upper lobe. Diagram insert illustrates degree of tracheal and carinal extension of the primary lesion. Note also the massive air shadow below left diaphragm produced by megacolon.

Fig. 11 (H. H.).—Postoperative x-ray film demonstrating position and outline of newly constructed airway following radical right pneumonectomy.

could not successfully be done with air, and plasma was injected into the right pleural cavity under considerable pressure. Again this repositioning of the mediastinum produced alleviation of the gastrointestinal symptoms and plasma has periodically been replaced in the thoracic cavity since that time. The patient was alive and well eight months following the original pneumonectomy, without evidence of recurrence of disease. It is our feeling that this patient presented persistent complete pyloric obstruction produced in some reflex fashion by faulty displacement of the mediastinum. This severe spasm did not respond to large doses of atropine or to Urecholine.

A third patient (Figs. 10 and 11) with advanced primary carcinoma arising in the right upper lobe with involvement of the carina and right lateral tracheal wall was operated upon in October, 1947. This patient presented the preoperative complication of a massive megacolon, which markedly displaced the left diaphragm upward. The patient's postoperative course was complicated

by an abdominal distention as well as an episode of acute gastric dilatation. Again these complications did not respond to Wangensteen suction alone, but required the maintenance of a positive pressure pneumothorax on the right. The patient was discharged from the hospital three weeks following surgery, but failed to return for pneumothorax refill and was admitted to the hospital in severe respiratory and abdominal distress three weeks later. Abdominal symptoms had been present for approximately five days and associated with

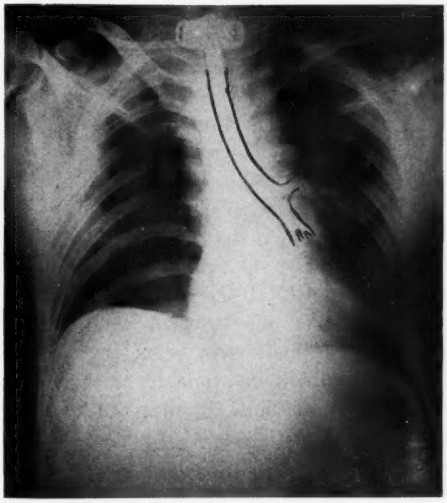


Fig. 12.

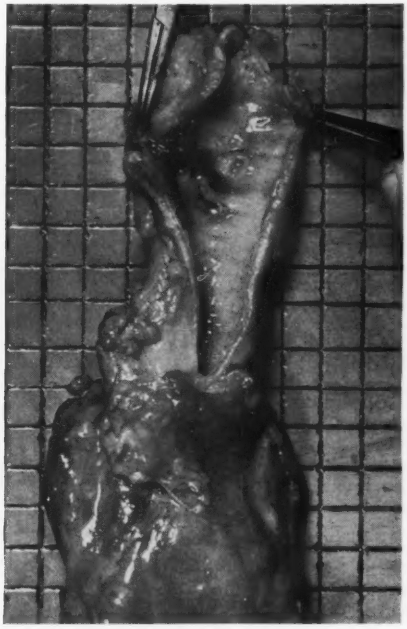


Fig. 13.

Fig. 12 (P. R.).—Portable x-ray film study of chest illustrating position of newly constructed airway after emergency right positive pressure pneumothorax. Left hilar shadow represents site of contralateral spread of tuberculosis. This patient had both carcinoma and active pulmonary tuberculosis in resected right lung.

Fig. 13 (P. R.).—Illustration of specimen of lower trachea and left main-stem bronchus obtained at autopsy 76 days following operation. Defect closed by transverse closure of longitudinal lateral eliptical defect. Satisfactory primary healing obtained. Two silk sutures visible at closure site appear loose and ready to be coughed up.

severe obstipation. A fecal impaction was removed, but adequate relief of symptoms was not obtained until reposition of the mediastinal structures had occurred. This patient was alive nine months following operation, without evidence of recurrence of disease.

A fourth patient (Figs. 12 and 13) with advanced primary right upper lobe carcinoma underwent similar operative procedure in December, 1947. No untoward difficulties were experienced at the operating table, but one hour following completion of the operation severe acute respiratory distress occurred, and it was found that the mediastinum had become markedly displaced toward the right, with considerable escape of air from the right pleural cavity into the

subcutaneous tissues. A bronchoscope was therefore inserted, noting marked kinking and obstruction of the trachea at the juncture of the trachea and the left main-stem bronchus on its left lateral wall. The patient experienced no difficulty as long as the bronchoscope was maintained in place but severe symptoms of anoxia immediately presented as soon as the bronchoscope was withdrawn up into the trachea. Finally a firm compression type of dressing was placed over the right chest and positive pressure pneumothorax instituted, allowing withdrawal of the bronchoscope and maintenance of an adequate airway. This patient was found to have both active tuberculosis and carcinoma in the removed right lung. A complete resection of mediastinal nodes was performed at the time of surgery and all these glands were found to be involved by metastatic disease. The patient had a stormy postoperative course, and finally appeared to be progressing well two months following operation when he developed signs of a transverse myelitis and died two weeks later. Autopsy revealed satisfactory healing of the repaired tracheobronchial juncture, no evidence of persistent malignant disease within the thorax. Very extensive metastatic disease was found about the entire thoracic portion of the spinal cord as well as diffuse metastatic lesions throughout the liver and peritoneal cavity.

The fifth patient (Figs. 14 and 15) in whom this type of procedure was carried out presented extremely extensive disease involving the carina and right lateral tracheal wall, with the apparent site of origin of the bronchiogenic carcinoma in the right upper lobe orifice. At the time of surgery it was found necessary to remove extremely extensive portions of the tracheal wall, the carina, and one inch of the medial wall of the left main-stem bronchus. Attempts at repositioning of the trachea and left main-stem bronchus were not possible, so that it was necessary to construct an artificial trachea out of a previously constructed glass tube. This was placed with special attention not to allow the lower portion of the tube to occlude the left upper lobe orifice by its left lower lateral surface. This artificial trachea was then surrounded by a large pleural graft. The postoperative course of this patient did not present the difficulties associated with right lateral displacement of the mediastinum as had been noted with the reconstructed tracheobronchial junctures in which no foreign body was utilized. However, this patient in whom a glass tube had been utilized in order to reconstruct the trachea presented considerable difficulties with excessive secretions and it was extremely difficult to control the resultant pneumonitis in the left lung. Despite the presence of a large tracheotomy, it was difficult to maintain adequate aeration and a clear airway. The patient developed an empyema in the right pleural cavity. No evidence of tracheopleural or bronchopleural fistula was present. The patient died twenty days following operation and at autopsy small areas of chronic pneumonitis were found in the left lung, but felt not adequate in amount to explain the patient's death. The pleural graft was found to be intact, and the glass tube had maintained a good position. There was a definite superficial necrosis of the bronchial mucosa at all points in which the glass tube had been in contact. The empyema in the right pleural cavity appeared to be under control. No evidence of persistent car-

cinomatous tissue was found within the thorax. The exact cause of death in this patient is not explained, but is felt to be due probably to a summation of several factors, namely, the chronic pneumonitis in the left lung, the empyema in the right lung, and some destructive changes in the liver which might well have been produced by prolonged anoxia.

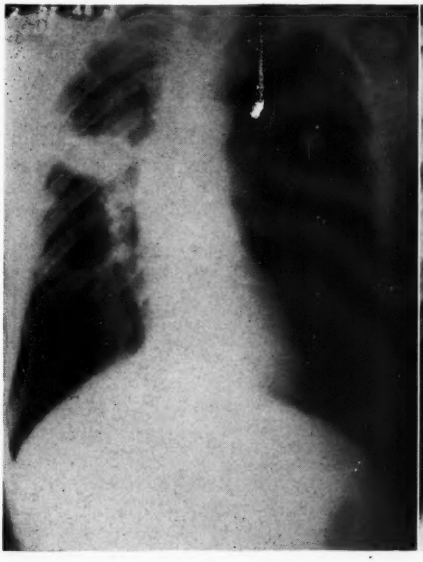


Fig. 14.

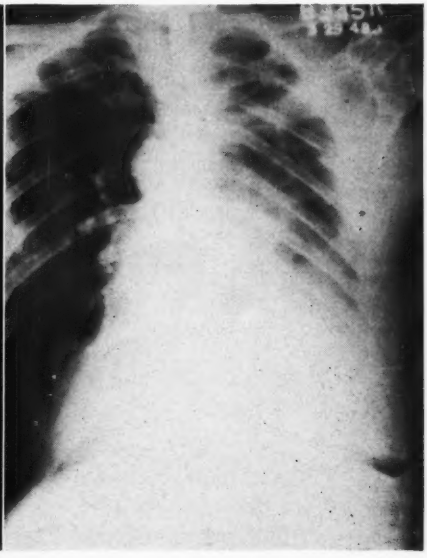


Fig. 15.

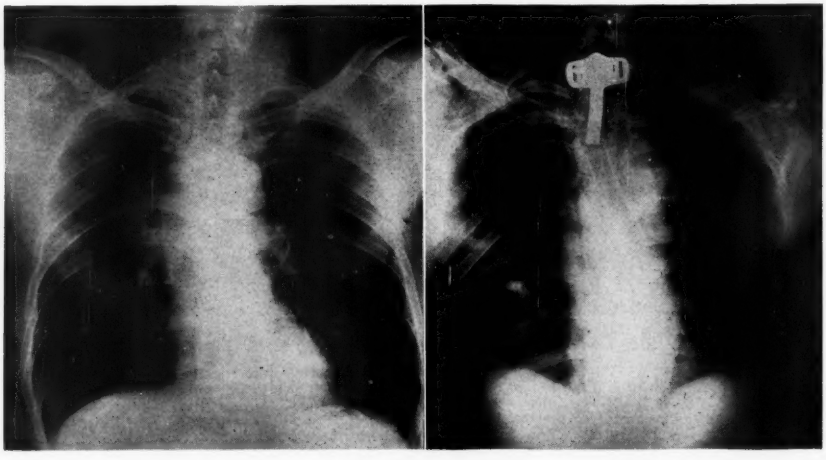
Fig. 14 (E. C.).—Posteroanterior view of chest showing obstruction of right upper lobe and main-stem bronchus. Tumor extended up the trachea and across the carina.

Fig. 15 (E. C.).—X-ray film of chest taken following extensive tracheal wall and left main-stem bronchial wall resection and radical right pneumonectomy. New airway constructed about a glass tube. This glass tube was essentially radiolucent.

It should be mentioned that in all the previously mentioned patients in whom this large area of tracheal reconstruction has been carried out, it has been our policy to institute an adequate-sized tracheotomy at the time of completion of the pneumonectomy. This was done in order to allow immediate access to the tracheobronchial secretions. It was also felt that the presence of a tracheotomy might decrease the pressure upon the suture line produced by strenuous coughing against a closed glottis. It is still our policy to carry out this routine tracheotomy with this procedure, and this was done in a sixth patient operated upon one month ago in whom a glass artificial trachea was again utilized (Fig. 16).

The actual salvage which may be derived from the application of this procedure to advanced right upper lobe carcinoma cannot as yet be evaluated. The first patient presented evidence of metastatic disease involving the upper portion of the right femur nine months following surgery, but is still alive with the disease at this time. The second and third patients were alive and

apparently well, without evidence of recurrence of disease eight and nine months following operation. The forth patient died due to metastatic disease two and one-half months following surgery. The fifth patient, in whom a glass tube was used for tracheal reconstruction, died on the twentieth postoperative day. The six patient was still within the first month of the postoperative course. Therefore, at the time of this writing two of the six operated patients have died. It is felt that the patient in whom the primary disease was a bronchial adenoma in which malignant degeneration had occurred has probably the best chance for eradication of the disease. Both this patient and the one with associated megacolon have been able to resume their preoperative occupations and have existed considerably longer, with much greater comfort, than other patients whom we have seen with carcinomatous involvement of the trachea and carina.



A. *B.*

Fig. 16 (J. E. W.).—*A*, X-ray studies before radical right pneumonectomy. Carcinoma presented extension into trachea and left main-stem bronchus. Massive defect following resection spanned by use of a glass tube and pleural graft.

B, X-ray studies after radical right pneumonectomy. Glass tube is visible on the postoperative film.

Despite the use of irradiation, palliative repeated bronchoscopic extirpation of obstructing tumor tissue and nitrogen-mustard therapy, the majority of patients whom we have seen with carcinoma involving the carina have died within two months following making of the diagnosis, with the longest survival time being six and three-fourths months.

Despite attempts at palliation by the usual conservative measures, patients with tracheal and/or carinal extensions of carcinoma rarely, if ever, regain a useful socio-economic status. In fact, they routinely follow a rapid downhill course of painful invalidism and progressive dyspnea. The rehabilitation seen in four of the six patients to date would appear to justify fully this procedure.

Certainly some patients in whom the disease is found at this stage may have asymptomatic extension of the neoplastic process to the liver or other silent areas. Also, there will be a definite percentage of patients presenting this syndrome in whom the lesion may prove inoperable at the time of exploration. Furthermore, it is hoped that with the increasingly early diagnosis of primary carcinoma of the lung, that extension upon the tracheal wall, or to the carina, will be less frequently seen. Certainly the procedure appears justified in the presence of a so-called bronchial adenoma, in which case it is potentially curative. Whether or not true primary carcinoma can be salvaged in this matter awaits further clinical observation and trial. In our opinion, definite palliative benefit is obtainable in this type of lesion.

The obstructive potential to the lumen of the airway, inherent upon the cartilage on the lateral aspect at the juncture of the trachea and left mainstem bronchus has been strongly demonstrated in our experience. It is hoped that experimental investigation will allow a satisfactory operative maneuver directly upon this cartilage to eradicate this complication. Until such time that this maneuver is obtained, extreme attention must be paid to maintaining the mediastinal contents slightly to the left of midline following this type of radical right pneumonectomy. Certainly it may be assumed, in view of the dramatic experimental work of Daniel relative to the construction of an artificial trachea, that the most satisfactory reconstruction of the tracheobronchial pathway should ultimately utilize his method.

CONCLUSIONS

1. A survery of the literature as well as the author's personal cases, still reveals that satisfactory early diagnosis of primary bronchiogenic carcinoma has not yet been obtained in most cases.

2. Primary bronchiogenic carcinoma is frequently found to arise in an upper lobe, as manifested by the finding of 51 primary upper lobe lesions in our personal group of 112 patients with this diagnosis.

3. It is felt that primary upper lobe carcinoma tends to present symptoms in a later stage of disease, due to a lesser inherent tendency to infection than that which occurs in lesions primary in the lower lobes.

4. Primary upper lobe tumors frequently achieve delayed final diagnosis, due to confusion of disease arising in this area with pulmonary tuberculosis.

5. A survey of our own personal cases and those at the Barnes Hospital, St. Louis, reveals a much higher percentage of lesions discovered in an inoperable stage when the tumor arises in an upper lobe. The most frequently inoperable lesion found is that arising in the right upper lobe. This is felt due to: (a) the immediate proximity of the superior vena cava and (b) the ease with which this lesion may involve the tracheal wall and carina. Diodrast outlining of the superior vena cava should be used prior to exploration of any right upper lobe tumor.

6. The author has presented a method which is felt applicable to neoplastic lesions arising in the right upper lobe area which seems to allow an extension of the indications for resectibility.

7. It is felt that this technique of resection should be utilized not only in patients in whom there is visible extension of tumor upon the tracheal wall and carina, but also in order to allow resection of an adequate margin of tissue proximal to carcinoma primary in the upper lobe bronchus. This should increase the potential cure rate.

8. The use of stabilization sutures has in our experience eradicated all of the dangers previously considered inherent upon the "open bronchial stump." With these sutures a defect 9 by 3 cm. in the lateral tracheobronchial wall has been left open without delivering oxygen or positive pressure to the remaining lung for a thirty-two minute interval without producing severe anoxia.

9. Experiences with the application of this procedure in six human patients are described, four in whom primary plastic reconstruction has been carried out. In two patients an artificial glass trachea was utilized. Certain complications attendant to this type of procedure are described in detail, as well as the methods utilized to counteract them.

10. It is felt that when no firm artificial support is utilized in this type of procedure, that constant attention must be given toward maintenance of the mediastinal structures slightly to the left of the midline. This may be maintained during the immediate postoperative period by the injection of air within the right pleural cavity, but soon requires a less compressible and more slowly absorbed substance such as plasma. The author has hesitated to utilize foreign bodies within the right pleural cavity such as Lucite balls, for fear of pressure erosion upon the suture line, or compression on the newly reconstructed airway.

11. It appears in patients in whom this procedure has been performed, that displacement of the mediastinum toward the right may produce acute or chronic gastric dilatation with pyloric obstruction. Correction of this complication has been achieved only by satisfactory reposition of the mediastinal contents. The mechanism of this reflex is not at present understood but does not appear to be produced by impulses carried by or produced through disturbance of the vagus nerves.

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PHRENIC NERVE PARALYSIS

Special Consideration of the Accessory Phrenic Nerve

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IT HAS seemed appropriate to make a careful study of the phrenic and accessory phrenic nerve relationships because of the fact that phrenic operations are employed quite extensively in treating certain types of pulmonary tuberculosis and because there is some lack of unanimity concerning the prevalence of accessory phrenic nerves.

Many authors have reported statistics on the incidence of accessory phrenic nerves found on cadaver dissections or at operation. Decker,[1] in dissections on seventy-two cadavers, found accessory nerves in 30 per cent, while at operation he was able to locate accessory phrenic nerves in only 15 per cent. Greenfield and Curtis[2] reported 24.4 per cent accessory nerves in 119 phrenic operations. Felix[3] stated that the accessory phrenic nerve frequency was between 20 and 30 per cent. Sauerbruch[4] found accessory nerves in 37.8 per cent. Ruhemann,[5] in dissections of seventeen cadavers, found accessory phrenic nerves in more than 50 per cent. Fisher[6] reported accessory nerves in 60 per cent of thirty-six operations. Aycock and Habliston[7] found accessory nerves entering the main phrenic nerve below the usual site of operation in 65 per cent of 130 cadavers. Goetze,[8] in dissections of twenty-five phrenic nerves on thirteen cadavers, found that phrenicotomy alone would have been unsuccessful in producing paralysis in 68 per cent. Alexander[9] estimated that "one or more accessory roots (some of which were probably the nerve to the subclavius) have been found in 99 per cent of the initial phrenic operations" in his clinic.

In order to arrive at an accurate conclusion concerning the prevalence of accessory phrenic nerves, it has been necessary to decide upon certain criteria which could be applied to the cases studied. There is practically never any question concerning the identity of the main phrenic nerve. This can usually be confirmed by the production of a diaphragmatic movement upon stimulation. If two main phrenic trunks are found to course downward along the anterior scalene muscle, neither one of these is classified as an accessory nerve. When stimulation of another nerve produces a definite diaphragmatic response, this nerve is considered to be an accessory phrenic nerve. When the main phrenic nerve has been paralyzed at operation and the ipsilateral hemidiaphragm continues to move, it is assumed that an accessory nerve exists. If, after that nerve has been located and severed, the diaphragm ceases to move normally, that is also conclusive proof of the existence of an accessory phrenic nerve. These criteria were used in the collection of statistics in this paper.

Two series of consecutive cases were studied, one of which was collected in Saranac Lake, N. Y. Sept. 14, 1944 to April 18, 1946, and the other in the

From State Tuberculosis Sanatoria of Connecticut.
Read (by title) at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

Connecticut State Tuberculosis Sanatoria, July 25, 1946 to June 5, 1947. All patients had at least one phrenic operation, and several repeat paralyses were performed. Some patients had the primary operation performed by another surgeon. If an accessory phrenic nerve were found on the next operation (by the author), such cases were included in this series.

In the entire series of 309 cases, there was conclusive proof of the existence of at least one accessory phrenic nerve in 75.7 per cent. It should be noted that another nerve in addition to the main phrenic nerve was found in 99.2 per cent. There is a definite possibility that some accessory phrenic nerves are so small that the impulses carried by them to the diaphragm are too weak to be detected by the operator. It is conceivable that these nerves, if allowed to remain intact, could gain sufficient power to cause the diaphragm to function quite well after a period of a few weeks or months. Many times a branching nerve was located. If no diaphragmatic response was noted upon stimulation of this nerve, it was not classified as a definite accessory nerve. It seems fair, however, to call this presumptive evidence of an accessory phrenic nerve. There are many anatomic dissections[1, 10] to show that the nerve to the subclavius muscle gives off a medial branch which joins the phrenic nerve. If these cases are included, the percentage increases from 75.7 to 80.9 per cent.

Because of the fact that there is occasionally some difficulty in locating the accessory phrenic nerve at operation, it seems appropriate to stress some specific points in technique which have proved to be of considerable practical importance. The patient is placed in the supine position with the head turned away from the side of operation. A small pad is placed under the back of the neck. It is most important to have a good view of the anatomic structures posterior to the clavicle. In order to obtain such a view, the operator must be able to stand at the upper end of the operating table and gaze downward into the depths of the incision. The regulation-type anesthesia screen, which is placed ordinarily over the patient's head before draping, is unsatisfactory because it interferes with this view. A special piece of apparatus (Fig. 1) has been devised which holds the drapes away from the patient's head and also gives the surgeon adequate room in which to work. This consists of a metal ring held in a horizontal position just above the patient's head by an upright bar which is fastened to the corner of the operating table. The position of the drapes is illustrated in the accompanying photographs (Figs. 2, 3, and 4). The usual phrenic incision is made parallel to and about 2 cm. above the clavicle just lateral to the clavicular portion of the sternocleidomastoid muscle. After severing a few of the platysma muscle fibers, the sternocleidomastoid muscle is retracted medially to expose the layer of fatty tissue directly over the anterior scalene muscle. This tissue is separated easily, and the phrenic nerve is almost invariably located at this level just as it crosses the anterior surface of the anterior scalene muscle. The sheath (of prevertebral fascia) is incised for a very short distance so that the nerve can be isolated, infiltrated with Novocain, and crushed. It is advisable to explore the anterior and medial aspects of the anterior scalene muscle for a second phrenic trunk. The operator then shifts his position from the side to the head of the operating table. By blunt dissection

along the lateral border of the anterior scalene muscle, a portion of the brachial plexus can be exposed as it courses downward and somewhat laterally beneath the clavicle. The accessory phrenic nerve can be found as it leaves the fifth root of the plexus and proceeds downward and somewhat medially. This may occur at a rather low level so that it is sometimes necessary to retract the

Fig. 1.—Phrenic ring placed at the left upper corner of operating table for right phrenic operation. Ring measures 10.5 inches in diameter. Transverse bar extends 3 inches beyond ring, and vertical bar is 18 inches in length.

Fig. 2.—Patient and ring in place for right phrenic operation. Head is turned to left side and neck is supported by a small pillow.

brachial plexus by gently grasping its sheath with a fine hemostat and lifting upward (Fig. 5). The accessory phrenic nerve will be found often to branch in the form of a "Y." The lateral branch is the nerve to the subclavius muscle, and the medial branch is the typical accessory phrenic nerve which eventually joins the main phrenic trunk in the chest a few centimeters below the level of the clavicle. A portion of this branching nerve, for a distance of about 1 cm., is

excised. Other accessory nerve fibers may be found at a higher or lower level. These are excised also so that it will not be necessary to explore this portion of the neck at a subsequent operation. A great variety of phrenic and accessory phrenic nerve relationships has been described by several authors. No attempt will be made to review this literature.[1, 10, 11]

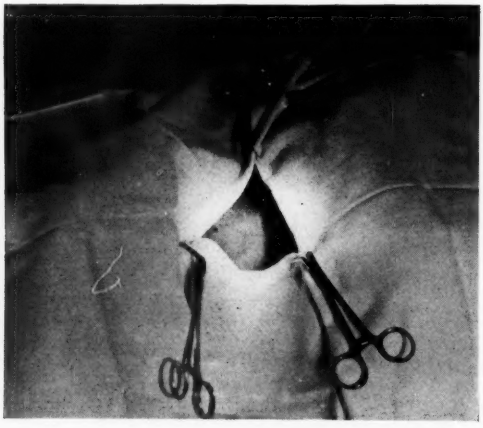

Fig. 3.—Drapes in place for right phrenic operation. The first three towels are placed to leave a triangular opening above the right clavicle. The fourth towel is draped across the ring over patient's head. This arrangement makes it possible for operator to stand above patient's head and look downward into incision.

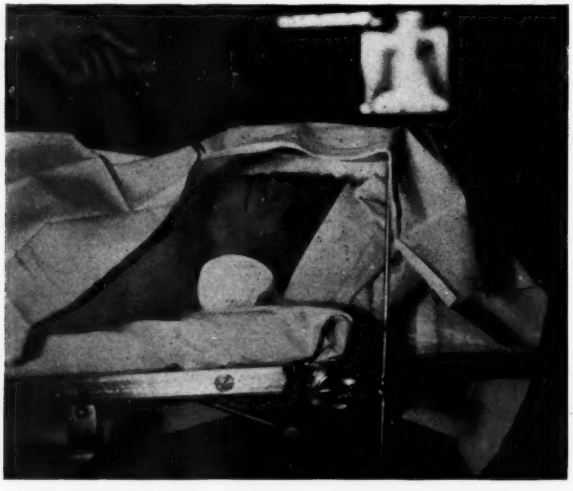

Fig. 4.—View from left side of table shows ample room for exchange of air.

After closure of the incision, the patient is taken immediately to the fluoroscopic room. If the leaf of the diaphragm on the side of operation is found to be moving, a re-exploration of the neck is carried out at once. In

most of these instances, another small accessory phrenic nerve will be found extending medially from the brachial plexus at a very low level beneath the clavicle.

There is some lack of agreement concerning the proper method to be used in testing for and determination of complete paralysis of the hemidiaphragm. Some authors[2] (Greenfield and Curtis) stated that, "The best method which we have found for demonstrating a successful paralysis of the hemidiaphragm is the 'sniff test.'" Alexander[9] stated that, "Hitzenberg's sniffing test is simple and especially useful." However, he continued, "When the patient sniffs suddenly and deeply a paralyzed, or even an incompletely paralyzed, hemidiaphragm is seen to undergo pronounced paradoxical movement." A positive "sniff test" indicates, therefore, that the affected leaf of the diaphragm is weaker than the opposite or normal side. Even though paradoxical motion is

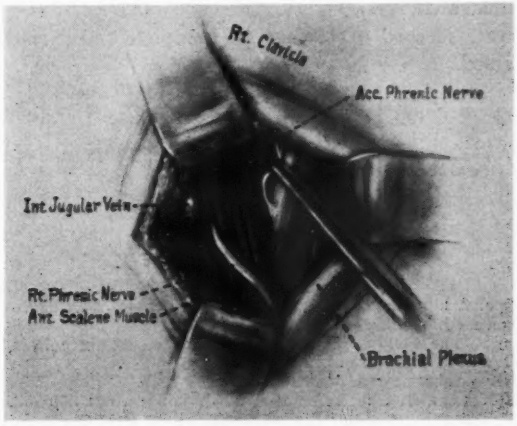

Fig. 5.—The right phrenic and accessory phrenic nerve viewed from above. The accessory nerve has been retracted upward by means of a hemostat. The medial branch extends downward beneath the clavicle to join the phrenic nerve, and the lateral branch is the nerve to the subclavius muscle.

noted on sniffing, another test is necessary to determine the presence or absence of complete paralysis. The most satisfactory test is performed as follows: The patient is asked to inhale deeply while the observer presses his two hands against the lower lateral portions of the ribs and watches the diaphragm fluoroscopically. A paralyzed hemidiaphragm will not move downward during this maneuver. If pressure is not exerted against the ribs, a costal breather may cause the ribs to flare sufficiently to produce a slight downward motion of a paralyzed diaphragm. If the diaphragm descends even slightly when the ribs are held in a fixed position, one should be strongly suspicious of a functioning accessory phrenic nerve in spite of the fact that there is paradoxical motion during the "sniff test." On several occasions, patients with these findings have been returned to the operating room and another accessory phrenic nerve has been located. Subsequent fluoroscopy almost invariably has shown complete paralysis of the hemidiaphragm with the deep-breathing, rib-holding test.

It is not the purpose of this paper to evaluate the benefits of phrenic nerve paralysis in pulmonary tuberculosis. Many authors[9, 12, 13, 14] have shown statistically that certain varieties of the disease improve more rapidly with a paralyzed diaphragm so that the phrenic operation has been widely accepted as a helpful procedure.

CONCLUSIONS

1. The importance of finding the phrenic accessory nerve in order to produce complete paralysis of the hemidiaphragm is discussed.

2. A series of 309 cases is presented in which the incidence of accessory phrenic nerves (75.7 per cent) is greater than that reported by most authors.

3. Details of technique of the phrenic operation are discussed with emphasis on aids to facilitate the location of accessory phrenic nerves.

4. An apparatus to provide better exposure of the field of operation is described and illustrated.

5. An accurate method of testing for complete paralysis of the hemidiaphragm is described.

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ELECTROPHRENIC RESPIRATION

IV. The Effectiveness of Contralateral Ventilation During Activity of One Phrenic Nerve

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IT HAS been demonstrated that the application of a cyclically undulating electrical potential to one phrenic nerve produces effective artificial respiration in the dog, cat, rat, monkey, rabbit, and man. The arterial oxygen and carbon dioxide levels could be maintained within normal limits by this method.[1-4] Complete control of the rate and depth of respiration could be maintained since, during electrophrenic respiration, motor activity of the respiratory center is suppressed.[3, 4] The mechanism of this respiratory suppression is largely vagal.

The fact that normal arterial oxygen levels could be maintained with the stimulation of only one phrenic nerve led to the assumption that one of two events was occurring in the contralateral lung during unilateral phrenic stimulation. Either the blood vessels of the contralateral lung, on which side the phrenic nerve was not being stimulated, were intensely constricted, thus shunting blood through the ipsilateral aerated lung, or, as seemed more likely, the contralateral lung was also being aerated. Jacobeus'[5] technique of differential bronchospirometry, whereby the relative ventilation of the right and left lung could be accurately determined, offered the most direct means of determining how much contralateral aeration was occurring during unilateral phrenic stimulation.

In previous communications concerning electrophrenic respiration, only those experiments were described in which nerve stimulation was accomplished by direct contact between the electrode and nerve. More recently, it has been found possible to produce electrophrenic respiration in man by placing the stimulating electrode on the skin directly over the motor point of the phrenic nerve just as it crosses the lateral ridge of the scalenus anticus muscle. The characteristics and results of electrophrenic respiration produced by external stimulation are the same as those obtained with the direct contact technique.[6]

METHOD

After anesthetization of the tracheobronchial tree with 0.25 per cent pontocaine, a bronchospirometric catheter of the type devised by Zavod[7] was introduced and the tip placed in the left main-stem bronchus under direct fluoroscopic control before inflating the retaining cuffs. The position of the bronchial catheter was checked by fluoroscopy and spot films during and after the procedure. The air spaces of the right and left lungs were then connected to

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Aided by a grant from The National Foundation for Infantile Paralysis.
Received for publication Sept. 16, 1949.
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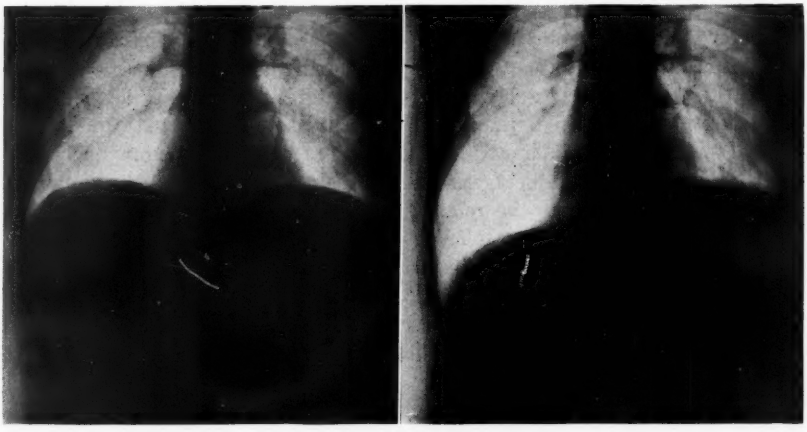
a Gebauer twin spirometer which recorded on moving paper. In subsequent illustrations, the upper tracing represents the ventilation of the right lung, the lower tracing that of the left lung.

Four patients with minimal tuberculosis, two with moderately advanced disease, and one normal volunteer were studied by differential bronchospirometry in respect to a comparison of electrophrenic respiration and spontaneous respiration. These patients were found to have normal or almost normal combined ventilatory function as established by maximal breathing capacity, vital capacity, walking ventilation, and spirometry. After several minutes of spontaneous respiration, during which time the rate, differential tidal volumes, and oxygen uptake of the two lungs were obtained, electrophrenic respiration was started. Tidal volumes, rate, and oxygen uptake from the two lungs were thus recorded during electrophrenic respiration and comparison made with the spontaneous values. Direct observation and, from time to time, fluoroscopic observation were used to be certain of the absence of spontaneous respiratory effort.



A. *B.*

Fig. 1.—Roentgenogram of chest during electrophrenic respiration with stimulation of the right phrenic nerve: *A*, during the resting phase of expiration; *B*, at the peak of inspiration. Note the pronounced descent of the right diaphragm, slight elevation of the left diaphragm, and shift of the mediastinum to the right.

Serial chest films were taken in rapid succession on one of us (S. J. S.) during several full cycles of electrophrenic respiration in order to demonstrate the changes in the position of the right and left sides of the diaphragm as well as the mediastinum during electrophrenic respiration (Fig. 1).

RESULTS

Fig. 1 illustrates the effect of right-sided electrophrenic respiration on the position of the right and left sides of the diaphragm and on the mediastinum. During inspiration the right side of the diaphragm descends, the mediastinum shifts to the right, and the left side of the diaphragm is slightly elevated. The two roentgenograms shown in Fig. 1 were made in rapid succession. Fluoroscopy

performed during electrophrenic respiration demonstrated that this sequence of diaphragmatic and mediastinal motions observed in Fig. 1 occurred under the experimental conditions described previously.

Differential bronchospirometry tracings were obtained twenty-one times during electrophrenic respiration and spontaneous respiration in seven subjects. The tracings were all suitable for the determination of differential ventilation. Nine tracings were taken for a sufficient length of time to be adequate for determinations of oxygen consumption.

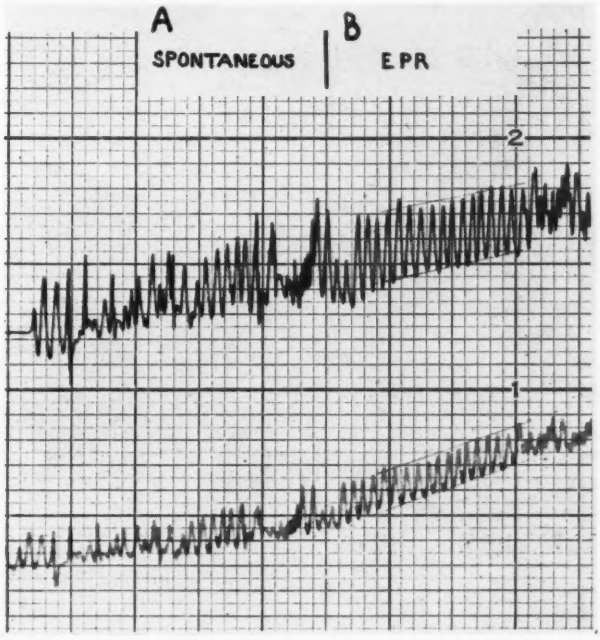


Fig. 2.—Differential bronchospirometry during spontaneous and right electrophrenic respiration. *A*, spontaneous respiration; *B*, electrophrenic respiration. Upper tracing, right lung; lower tracing, left lung (see Table I).

The results are listed in Table I. During electrophrenic respiration by means of unilateral phrenic stimulation, the contralateral lung was always adequately ventilated. At a rate close to that of the patient's spontaneous rate, electrophrenic respiration produced relative ventilation of both lungs not significantly different from the relative ventilation observed during spontaneous respiration (Patients J. P. and W. R.). As the rate was increased, the proportion of the total ventilation performed by the contralateral lung sometimes decreased (Patients J. P., W. R., J. M., and M. M.). The magnitude of this change, however, was never striking. The decrease in percentage ventilation of the contralateral lung never exceeded 12 per cent of the total at electrophrenic rates up to twice the spontaneous rate. This was true despite the fact that, in

TABLE I. DIFFERENTIAL VENTILATION, OXYGEN CONSUMPTION, MINUTE VOLUMES, AND VENTILATORY EQUIVALENTS DURING SPONTANEOUS AND UNILATERAL (RIGHT) ELECTROPHRENIC RESPIRATION

PATIENT	TYPE OF RESPIRATION	RATE	VENTILATION		O_2 CONSUMPTION		MINUTE VOLUME (C. C.)	VENTILATORY EQUIVALENT		REMARKS
			PER CENT RIGHT	PER CENT LEFT	PER CENT RIGHT	PER CENT LEFT		RIGHT	LEFT	
A. R.	Spontaneous	12	53	47	52	48	6,960	2.2	2.1	Normal volunteer
	EPR	48	53	47	--	--	7,220	--	--	
M. M.	Spontaneous	15	51	49	37	63	6,750	3.9	2.2	Pulmonary tuberculosis, moderately advanced, asymptomatic; small area of cavitation, right upper lobe
	EPR	24	63	37	35	65	10,800	6.9	2.2	
	EPR	25	61	39	36	64	10,370	5.0	1.7	
	EPR	48	67	33	--	--	7,520	4.5	2.4	
J. P.	Spontaneous	10	64	36	63	37	5,150	2.2	2.1	Pulmonary tuberculosis, minimal; infiltrative disease, left upper lobe
	EPR	12	64	36	--	--	5,280	--	--	
	EPR	18	72	28	67	33	7,200	2.5	2.0	
	EPR	22	75	25	--	--	5,520	--	--	
	EPR	34	76	24	--	--	9,860	--	--	
W. R.	Spontaneous	18	56	44	60	40	8,550	3.3	4.0	Pulmonary tuberculosis, minimal, asymptomatic; minute infiltrative lesion, left upper lobe
	EPR	20	58	42	60	40	12,000	6.0	6.3	
	EPR	31	63	37	--	--	11,010	--	--	
	EPR	31	65	35	--	--	10,550	--	--	
	EPR	42	67	33	59	41	13,870	3.9	2.7	
	EPR	44	58	42	--	--	13,640	--	--	
R. P.	Spontaneous	15	60	40	67	33	5,480	1.9	2.5	Pulmonary tuberculosis, minimal; left apical infiltration, left pleural effusion
	EPR	27	69	31	67	33	7,510	2.2	2.1	
P. F.	Control	9	58	42	18	82	9,000	8.8	1.3	Pulmonary tuberculosis, moderately advanced; multiple cavitation, upper half right lung
	EPR	25	60	40	21	79	15,620	9.4	1.7	
J. M.	Spontaneous	12	67	33	60	40	6,600	2.6	1.9	Pulmonary tuberculosis, minimal, asymptomatic; minimal bilateral, apical infiltration
	EPR	18	75	25	--	--	10,090	--	--	
	EPR	22	75	25	61	39	10,560	2.3	1.2	
	EPR	24	77	23	61	39	10,320	2.3	1.1	
	EPR	32	80	20	--	--	11,800	--	--	
	EPR	32	80	20	--	--	16,000	--	--	
	EPR	36	83	17	--	--	15,120	--	--	

every case, the minute ventilation during electrophrenic respiration was appreciably in excess of that during spontaneous respiration. In no case did the percentage decrease of contralateral lung ventilation diminish more than 16 per cent of the total, even at exceedingly rapid rates.

Figs. 2 and 3 show recordings of differential ventilation obtained during spontaneous and then electrophrenic respiration.

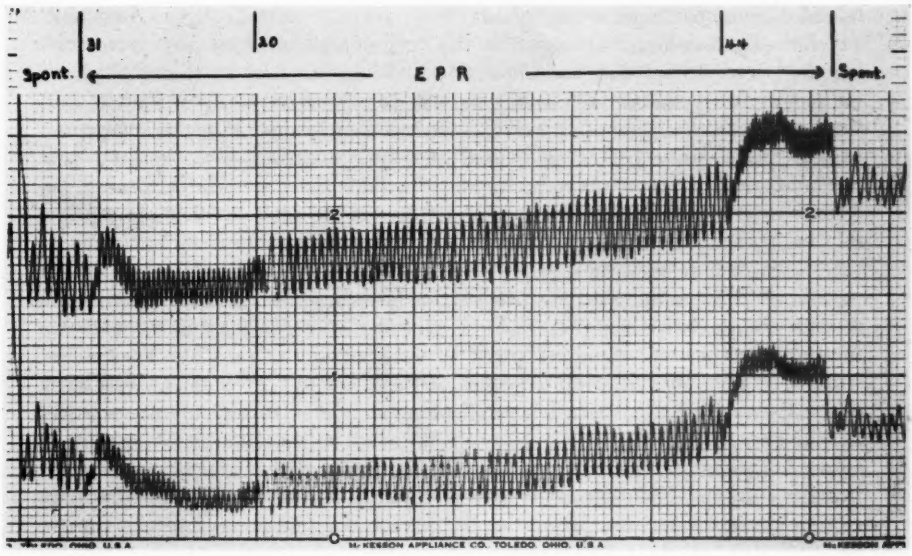


Fig. 3.—Differential bronchospirometry during spontaneous and right electrophrenic respiration at varying rates. Patient W. R. in Table I. Spontaneous respiration followed by EPR at rate of 31 per minute, 20 per minute, and 44 per minute. The last segment is again spontaneous respiration. Note the similarity of the differential ventilation during spontaneous and electrophrenic respiration.

DISCUSSION

The preceding data resolve the question of the mechanism whereby unilateral stimulation results in normal arterial oxygen saturation during electrophrenic respiration. It is clear that bilateral pulmonary ventilation occurs. It has previously been demonstrated that, within a few seconds after the onset of electrophrenic respiration, spontaneous respiratory effort ceases.[3, 4] In addition to published data on this point, data are available from animal experiments in which action potentials were recorded from the unstimulated side of the diaphragm and intercostal muscles before and during right-sided electrophrenic respiration. They showed that all respiratory motor impulses ceased during electrophrenic respiration.[8] This being the case, the ventilation of the contralateral lung must, in some way, be related to the motion of the ipsilateral (stimulated) diaphragm. The stimulated side of the diaphragm descends and expands the lung on that side; the mediastinum shifts toward the stimulated side in response to differentially created negative intrapleural pressure, thus expanding

the contralateral lung, almost to the same degree as the lung on the stimulated side. The uncontracted contralateral leaf of the diaphragm is elevated slightly, its ascent probably being limited in part by its continuity with the contracted side of the diaphragm through the central tendon.

Tracings in Figs. 2 and 3 and the data in Table I demonstrate that the differential tidal volume percentages and oxygen consumption of the lung on the unstimulated side during electrophrenic respiration approach the values obtained during spontaneous respiration.

Stenosis Breathing.—Because of the very special circumstances surrounding the bronchospirometric technique, conclusions arrived at by this method are limited in two respects. First, the patient is not under basal conditions and thus successive data obtained are not always comparable as to their absolute values. The relative percentage which each lung contributes to the total performance does, however, remain the same in the absence of unilateral interference with pulmonary function. Any change or lack of change in these relative percentages is thus significant. With the exception of minute ventilation, only such relative data have been reported herein and conclusions drawn pertain only to them. Second, because the bronchospirometric catheter has to contain within its envelope four separate lumina—two for the airways and two for the inflatable cuffs—and still must be small enough to pass into the trachea without injury to the vocal cords, a certain amount of stenosis breathing cannot be avoided. This effect is small or negligible at resting minute volumes but becomes so large at high air flow velocities that ratios of maximal ventilatory efforts obtained by this method are of little value. The present data might thus be questioned in that electrophrenic stimulation may create greater than resting air flow velocities. However, by this method, diaphragmatic motion can be controlled both in extent and in rate to such a degree that the spontaneous resting minute volume and resting respiratory rate can be closely simulated (Table I and Fig. 2). Several of our tracings illustrate the fact that only when the diaphragm is stimulated to exchange much larger than spontaneous volumes of air at several times the resting rate does the effect of stenosis breathing become apparent in some instances. The passive contractile force of the lungs and thorax is then unable to expel the entire volume of air which was forcibly introduced during inspiration by the powerful action of the diaphragm. The functional residual air thus increases but upon return to electrically controlled slower rates or spontaneous respiration it promptly returns to its former value (Fig. 3). Additional evidence can be presented that stenosis breathing effects do not invalidate results reported at or near resting respiratory rates and resting minute volumes:

1. In all cases presented the percentage of minute volume which each lung contributes with unilateral electrophrenic stimulation is equal or nearly equal to the spontaneous ratio at resting or near resting minute volumes. Only when the rate and minute volumes are much larger than the spontaneous one does the ratio of ventilation shift somewhat in favor of the stimulated side. It is exactly under these conditions that stenosis breathing begins to play a large role.

2. The mechanism which we hold responsible for the ventilation of the lung on the nonstimulated side is mediastinal shift. This can be demonstrated by fluoroscopy or serial roentgenograms with and without the obstructing catheter in situ (Fig. 1).

3. The rise of the functional residual air from the resting base line (or midcapacity) which occurs when one diaphragm is stimulated at a much higher than resting rate occurs on both sides to an equal or almost equal extent. This illustrates not only that stenosis effects do not greatly, if at all, favor the stimulated side, but also that the force which causes an inrush of air into the lungs is equally applied to both sides, or almost so (Fig. 3).

Phrenic Nerve Interruption.—The fact that the mediastinum can swing sufficiently to maintain normal ventilation of the lung opposite to the stimulated side is of great interest since electrophrenic stimulation is used as a means of artificial respiration. It is further of interest in connection with the interruption of the phrenic nerve to provide pulmonary collapse and "rest" in the treatment of tuberculosis.

In order to re-evaluate any benefit of such an operation in the light of the above data, it is first necessary to attempt to define pulmonary collapse and "rest." Because of the ever-recurring confusion in the literature, it must be pointed out that collapse and rest are not synonymous. Collapse therapy is usually defined as any procedure which will cause a reduction in lung volume. "Rest" implies "functional elimination" or reduction in the share of work, for example, ventilation which the lung is called upon to perform. Which of these factors play a dominant role in the therapeutic effect varies with the type of treatment. Thus the often dramatic improvement which follows a period of bed rest is due, only to some extent, to collapse following the reduction in lung volume incident to the horizontal position of the body. Rest here appears to play a major role. In certain other situations rest enters the picture only to a very small extent, if at all. Pneumothorax induced on an only remaining lung following contralateral pneumonectomy or pneumoperitoneum with equal bilateral rise of the diaphragms are cases in point.

There appears to be no question that unilateral phrenic nerve interruption causes a degree of collapse or reduction in lung volume. Measurement on corpses has shown a decrease of 15 to 30 per cent of the volume of the involved hemithorax following phrenic nerve interruption.[9] Lindskog and Friedman[10] studied lung volumes in seven cases before and after temporary phrenic nerve interruption. They were able to show an average reduction of about 10 per cent of the functional residual air after operation. There appears to be less agreement of the effect of diaphragmatic paralysis on vital capacity and maximum breathing capacity. While Gaubatz[11] and Ruttgers and Smilovits[12] reported reduction in these values of as much as 30 per cent, Warring,[13] Wright,[14] and Wright and Woodruff[15] found little or no alterations in maximum breathing capacity and vital capacity following this operation. In nine patients studied before and fourteen days after phrenemphraxis we found a mean reduction of 10 per cent of maximum breathing capacity and 16 per cent of vital capacity.[16] Two variables make comparison of such studies difficult. The first

is the extent of denervation of the diaphragm since accessory nerves are occasionally overlooked even if they are diligently sought. The second is the time elapsed between nerve interruption and ventilatory tests. Studies of others and our own are in agreement that any reduction in pulmonary volumes and breathing capacities, if they occur, return to the preoperative values long before diaphragmatic motion returns. A far better evaluation of reduction in lung volume might be obtained by the bronchospirometric technique employed before and after operation. No such reports have appeared in the literature. The well-known difficulties of reliable residual air determinations together with the problems involved in bronchospirometry may account for this. We have been successful in this attempt in only two cases. In both there was a satisfactory rise in the diaphragm in the treatment of minimal disease. In one, the lung volume on the phrenicectomized side was decreased 17 per cent four weeks after operation, and in the other, 11 per cent two weeks after operation.[16]

No factual evidence has been reported in the literature concerning the degree of rest which diaphragmatic paralysis affords. Even co-authors of the same book disagree on this point. While Pinner[17] felt that the factor of rest is slight because of compensatory increase in lateral expansion of the chest and increased motion of the upper ribs, Alexander[17] was "strongly of the opinion that paralysis of a freely moving diaphragm greatly rests the lung." In evidence he cited cases where clinical improvement was evident following phrenic paralysis in the absence of elevation of the diaphragm. The only adequate way to demonstrate a relative decrease in ventilation and blood flow of the lung on the denervated side is bronchospirometric evaluation. In nine cases studied by us and cited previously, the relative ventilation changed only 3 per cent after operation.[16] In the absence of hypoxia it can also be presumed that there was no change in relative blood flow.

The present studies with electrophrenic respiration not only support the preceding findings but also offer an explanation for them, namely compensatory ventilation by mediastinal swing. At respiratory volumes and rates approximating those of the resting state, the mediastinum has been shown to provide a normal relative ventilation and oxygen consumption for the lung in the absence not only of diaphragmatic action but also of intercostal activity. Phrenic interruption may cause a certain amount of collapse or reduction in lung volume thus relaxing elastic tissues, promoting scar formation, and perhaps causing small local areas to rest due to differential elasticity of normal and diseased areas. On the other hand, in the absence of a fixed mediastinum, phrenic nerve interruption does not provide any degree of general rest for the lung because of the ventilatory effects of the mediastinal shift under these circumstances. The element of pulmonary rest as defined previously is, therefore, not likely to be an important factor in whatever therapeutic benefit the patient obtains from phrenicectomy.

CONCLUSIONS

1. Seven patients were respired by means of externally applied electrophrenic respiration capable of maintaining adequate arterial oxygen saturation.

During this procedure it was found that ventilation of the contralateral as well as the ipsilateral lung occurred as determined by differential bronchospirometry.

2. This is caused by the shift of the mediastinum to the stimulated side thus causing the expansion of the contralateral lung. This is followed by a slight elevation of the unstimulated side of the diaphragm.

3. These data suggest that the therapeutic benefit from phrenic nerve interruption, if any, results primarily from partial parenchymal collapse rather than from decreased ventilation (rest).

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PULMONARY FUNCTION STUDIES BEFORE AND AFTER EXTRAPLEURAL PNEUMONOLYSIS WITH PLOMBAGE

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PRESERVATION of the maximal amount of pulmonary function compatible with adequate control of disease has always been the goal of collapse therapy in pulmonary tuberculosis. Development of newer methods in the evaluation of pulmonary function has made it possible to choose procedures for patients with markedly impaired function which will contribute no noteworthy reduction of function yet will adequately control the disease process.

For the past two years extrapleural pneumonolysis with Lucite (methyl methacrylate) plombage has been performed at this institution. A major indication for the use of this procedure has been in patients with such severely reduced pulmonary function that thoracoplasty, which would ordinarily be the method of choice, could not be done with reasonable assurance of postoperative survival. In others the extrapleural procedure was chosen because of the expectation of bilateral collapse therapy where the necessity for preservation of function is obvious.

This paper presents the results of function studies on nine patients before and after insertion of Lucite spheres in the extrapleural space. The methods of function testing have been adequately described elsewhere and need no elaboration here other than a brief statement of the various procedures used. These included: maximum breathing capacity (M.B.C.), breathing reserve (B.R.) from rest to voluntary maximum ventilatory effort, lung subdivisions, and oxygen consumption, plus ventilation in the recovery period after a standard exercise test. After completion of these studies from which an estimation of total pulmonary function was gained, divided function of the separate lungs was done using the bronchospirometric methods of Jacobaeus,[1] Gebauer,[2] and Zavod.[3] It is from this latter procedure that the most illuminating information could be secured after it had once been shown that total function could sustain a surgical intervention.

CASE PRESENTATIONS

A. W., a 43-year-old white woman, had the onset of pulmonary tuberculosis in 1933, with a minimal lesion in the left apex. A left pneumothorax was initiated in 1933, and maintained for fourteen years. In 1935, a lesion was noted in the right apex for which

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right pneumothorax was attempted unsuccessfully. A right phrenic crush was done in 1937, which controlled the disease until 1942, when pneumoperitoneum was instituted for reactivation of disease. Between 1942 and 1947, when she was admitted to this hospital, repeated hemoptyses were noted and the lesion on the right had progressed to frank cavitation. The pneumothorax on the left was still present. Pulmonary function studies at that time revealed an M.B.C. of only 30.7 liters per minute and a B.R. of 23.5 liters per minute. All other studies (Table I) were likewise markedly reduced. It was felt that this patient's function could not support surgery at this time.

A program of graded activity was devised for this patient in an attempt to increase her ventilatory capacity. This consisted of breathing and walking exercises. Under this program the left lung re-expanded and when retested six months after admission the M.B.C. had risen to 36 liters per minute with an increase in B.R. to 29.4 liters per minute. Bronchospirometry showed the right lung to be carrying on 76 per cent of total oxygen consumption and 78 per cent of total ventilation. Further exercise enabled this patient to increase the M.B.C. to 56.7 liters per minute and B.R. to 49 liters per minute. Bronchospirometry showed the right lung to be carrying on 87 per cent of total oxygen consumption and 85 per cent of total ventilation respectively. At this time it was agreed to collapse the right apex by extrapleural Lucite plombage.

In June, 1947, the extrapleural pneumonolysis was performed. Postoperative course and convalescence were uneventful. Four months following surgery the patient was retested and showed an M.B.C. of 50 liters per minute, a loss of only 6 liters from the preoperative figure. B.R. was 44.2 liters, a loss of 4.86 liters per minute. Bronchospirometry showed the right lung to have 87 per cent of total ventilation and 75 per cent of total oxygen consumption.

Comment.—In this patient the problem was one of enabling her to reach a satisfactory total pulmonary function level before surgery could be attempted. Bronchospirometry then revealed that most of the function was in the right lung which was the lung to be collapsed. The extrapleural procedure was chosen because it was felt that the collapse could be confined to the involved portion of the lung and that encroachment on healthy respiring tissue could be reduced to a minimum. These views seem to be substantiated by postoperative study in which the total loss in the M.B.C. was 6 liters per minute.

B. M., a 37-year-old white woman, had tuberculosis dating from 1931. In 1933, bilateral upper lobe cavitation was present and the patient spent one year on bed rest. In 1934, attempted bilateral pneumothorax was unsuccessful. A left phrenic crush was done at this time. In 1935, right phrenic crush was performed. The patient's status had improved, sputum was negative, but the patient was still on bed rest. By 1940, the sputum was positive again, and the right phrenic was recrushed. The sputum remained positive following this latter procedure and continued consistently positive until 1948, when an extrapleural pneumonolysis with Lucite plombage was performed on the left.

Studies before surgery revealed a borderline function, with an M.B.C. of 40 liters per minute. Performance during exercise revealed mild dyspnea on the step test but recovery was rapid. Bronchospirometric evaluation showed the right lung to be carrying 77 per cent and 76 per cent of the total oxygen consumption and ventilation, respectively. Function testing was repeated three months after surgery, showing no decrease in total function in that the M.B.C. and performance on the step test was the same as in the preoperative period. Bronchospirometry now showed the right side to be carrying 73 per cent and 70 per cent of the total oxygen consumption and ventilation.

Comment.—This patient has the characteristic bilateral fibroid type of tuberculosis. Multiple phrenic operations plus obliteration of the pleural space had reduced the pulmonary function to the point where very little reserve was

TABLE I

CASE	STATE	TOTAL FUNCTION							SIDE (LUNG)	BRONCHOSPIROMETRY			
		R.M.V. (LITERS PER MIN.)	V.C. (C.C.)	M.B.C. (LITERS PER MIN.)	B.R. (LITERS PER MIN.)	B.R. (% AT REST)	B.R. (% 1ST MIN. REC.)	V.E.		OXYGEN CONSUMPTION		VITAL CAPACITY	
										C.C.	PER CENT	C.C.	PER CENT
1. O. E., left extrapleural	Preop.	10.4	2,375	44.1	33.7	76	65	2.2	Right	250	67	975	61
									Left	125	33	625	39
	Postop.	10.0	2,175	43.0	33.0	76	65	1.4	Right	320	63	1,360	79
									Left	200	37	360	21
2. C. B., right extrapleural	Preop.	7.7	1,075	38.6	30.9	80	71	2.2	Right	50	12	175	29
									Left	375	88	425	71
	Postop.	6.8	1,100	32.0	25.2	79	61	2.1	Right	0	0	100	9
									Left	250	100	1,000	91
3. L. B., right extrapleural	Preop.	5.0	1,725	76.0	71.0	93	88	1.5	Right	50	14	275	17
									Left	325	86	1,375	83
	Postop.	4.2	1,485	75.0	70.8	94	89	1.2	Right	60	17	200	14
									Left	300	83	1,200	86
4. B. M., left extrapleural	Preop.	4.9	1,475	40.0	35.1	87	78	1.6	Right	250	77	1,010	76
									Left	75	23	325	24
	Postop.	6.0	1,270	41.0	35.0	85	79	1.8	Right	245	83	1,000	80
									Left	50	17	250	20
5. M. M., right extrapleural	Preop.	6.9	2,000	84.3	77.4	91	89	2.0	Right	210	50	1,000	67
									Left	210	50	500	33
	Postop.	7.5	1,800	98.0	90.5	92	90	2.3	Right	150	37	750	43
									Left	250	63	975	57
6. L. H., left extrapleural	Preop.	6.9	1,475	48.2	41.3	85	75	2.7	Right	200	62	1,075	70
									Left	125	38	450	30
	Postop.	6.8	1,425	46.4	39.2	85	72	2.7	Right	200	66	1,050	72
									Left	100	34	400	28
7. A. W., left extrapleural	Preop.	7.7	1,450	56.7	49.0	86	79	2.2	Right	325	87	1,075	85
									Left	50	13	190	15
	Postop.	5.8	1,200	50.0	44.2	88	80	1.6	Right	225	75	975	87
									Left	75	25	150	13
8. O. M., left extrapleural	Preop.	6.7	2,425	59.2	52.5	88	70	2.1	Right	525	100	450	25
									Left	0	0	1,400	75
	Postop.	6.6	2,000	58.0	51.4	88	72	2.0					
	Preop.	8.4	3,350	119.4	111.0	93	89	2.5					
9. L. G., bilateral extrapleural	Postop., right extrapleural	7.1	3,000	116.6	109.0	93	88	2.0	Right	150	57	1,175	45
									Left	112	43	1,200	55
	Postop., left extrapleural	7.9	3,000	117.2	109.3	93	86	2.4	Right	230	44	1,025	41
									Left	290	56	1,475	59

left. It was felt that an extensive surgical procedure involving collapse of respiring tissue would have in all probability relegated this individual to the ranks of the bedfast. The extrapleural plombage was performed as a calculated risk and it appeared not to have affected the patient's function to any appreciable extent.

C. B., a 29-year-old white woman had the onset of tuberculosis some fifteen years before admission to this institution. At different times she had had bilateral upper lobe cavitation for which she had received artificial pneumothorax and phrenic crush, both on the left. Artificial pneumothorax had been initiated some four years before admission to this hospital. On examination here the patient revealed an active process in the right upper lobe with cavitation and a paralyzed right hemidiaphragm. A therapeutic pneumothorax was present on the left. Sputum was highly positive. The pneumothorax on the left was re-expanded and pulmonary function testing was done. Total function was seriously diminished, the M.B.C. being 33.2 liters per minute, and vital capacity 1,150 c.c. The standard exercise test was performed with marked dyspnea and prolonged recovery. A program of breathing exercises and walking activity was started with the hope of increasing function. In six months the M.B.C. had risen to 38.6 liters per minute with definite improvement in the performance of exercise. Bronchospirometry showed the left lung to be carrying 89 per cent of the total oxygen consumption and 71 per cent of the ventilatory function. An extrapleural pneumonolysis with Lucite plombage was performed on the right. Retesting six months after surgery revealed some decrease in total pulmonary function with an M.B.C. of 32.0 liters per minute although there was no clinical evidence of increased dyspnea. Bronchospirometry showed the left lung to be carrying 95 per cent of total oxygen consumption and 93 per cent of total ventilation.

Comment.—This girl had an even more seriously diminished function than the previous case. Because of her youth and the weak prospects for recovery without surgical intervention, the plombage was performed. As demonstrated by the function testing, a decrease in total function did occur, but not of sufficient magnitude to incapacitate markedly this patient.

L. H., had initial tuberculosis, consisting of bilateral apical involvement with cavitation on the left, which was discovered some ten years prior to admission to this hospital. A left pneumothorax and left phrenicectomy failed to control this lesion, the right apex having become stabilized in the interim. X-ray examination at the time of admission showed fibrocavernous disease in the left upper lung with a raised, paralyzed diaphragm on the left. The right lung showed apical fibrosis with some basal emphysema and upward retraction of the right hilar structures. Function studies showed an M.B.C. of 48.2 liters per minute with mild dyspnea on the standard exercise test. Bronchospirometry showed the right lung to be carrying 62 per cent of the total oxygen consumption and 70 per cent of the ventilation. Left extrapleural pneumonolysis with Lucite plombage was done. Retesting some four months postoperatively revealed a reduction in M.B.C. to 46.4 liters per minute, a loss of 1.8 liters with no change in the performance of exercise. Bronchospirometry showed the right lung to be carrying 66 per cent of total oxygen consumption and 72 per cent of total ventilation.

Comment.—This case demonstrates a minimal loss in function following the surgical collapse procedure. This negligible decrease may be interpreted as being due to collapse only of nonfunctioning parenchyma or, as demonstrated by Björkman[4] and others, may possibly be a compensatory increase in the function of the contralateral lung.

The other five cases in this series, which will not be described in detail, are of the same order, in that loss in total function was held to a minimum. In one

case there was a significant rise in the M.B.C. after Lucite plombage though bronchospirometry showed a decrease in oxygen consumption and ventilation of the collapsed side (Case 5). This is again interpreted[4] as indicating the inherent reserve of the uncollapsed side which responds with greatly increased function when greater demands are placed on it by collapse of the contralateral lung.

Although the statistical validity of such a small series is naturally subject to question, we have nonetheless determined the percentage decrease which was found following surgery in three of the tests (M.B.C., V.C., and oxygen consumption) used to evaluate pulmonary function.

In the total of nine cases studied, the M.B.C. was decreased by an average of 5.9 per cent (3.02 liters per minute) in seven cases, while two revealed an increase of 2 per cent (1 liter per minute) and 14 per cent (13.7 liters per minute) respectively over the preoperative figures. Bronchospirometric determination of oxygen consumption on the operated side revealed four cases with an average decrease of 8.7 per cent, while four showed an increase of 5.6 per cent. Vital capacity was decreased in eight cases by an average of 12 per cent with one case showing a postoperative increase of 3 per cent.

DISCUSSION

A recent survey of the literature reveals the presence of only one article devoted to a study of the comparative pulmonary function before and after surgical extrapleural pneumonolysis. In 1948, Vaccarezza and associates[5] reported the results of a functional study of this type carried out on a series of ten patients with pulmonary tuberculosis. His results showed an average decrease in the vital capacity of the collapsed lung of 28 per cent and a 24.3 per cent decrease in the oxygen consumption. As previously noted, the absolute loss of function in our series of cases was of minimal degree. The discrepancy between the figures obtained by Vaccarezza and ourselves can readily be explained if the roentgen reproductions and the clinical data which is supplied in the body of his article are examined. It at once becomes apparent that the extrapleural stripping and resultant pneumothorax space produced by the South American group was greater than in any of the cases in our series, so that one would logically expect the greater collapse to produce a more marked decrease in function. In addition, the extrapleural space in Vaccarezza's series was maintained with air under atmospheric or positive pressures which would in itself further reduce the expansion of the lung in inspiration. Thus, the two series are not comparable in that our specific aim was to produce a surgical collapse of only sufficient degree to control the disease process while at the same time sparing the existing pulmonary function in those selected patients who revealed markedly reduced total function prior to surgery.

SUMMARY

1. Nine patients with pulmonary tuberculosis are presented upon whom pulmonary function was studied before and after surgical extrapleural pneumonolysis with Lucite plombage.

2. Results would indicate that only minimal decrease in function may be expected following this type of surgery.

3. Extrapleural pneumonolysis may be the procedure of choice in those selected cases where conservation of existing pulmonary function becomes a necessity.

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BENIGN FIBROMA OF CHEST WALL

Report of a Case

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THE occurrence of primary intrathoracic neoplasms seems to be on the increase, more apparent than real, as indeed are most neoplastic growths, and for essentially the same reason. This is mainly due to the employment of modern diagnostic methods, which fact is particularly applicable in the case of chest tumors because of the increasing widespread practice of mass roentgen-ray examination of the chest and the "awareness" of the present-day practitioner of these relatively silent but dangerous growths.

The most important and most frequent intrathoracic tumors are of pulmonary or bronchiogenic origin and the copious literature on this type is testimony of the fact. Second in frequency are mediastinal tumors and least frequent, or comparatively rare, are the neoplasms arising from the wall of the thorax and extending into the thoracic cavity.

Metastatic neoplasms of the bony thorax are, of course, frequent, but primary tumors arising from the connective tissue of the chest wall are rare. Intrathoracic fibroma is reported as an extremely rare tumor and up to October, 1941, Blades[1] found only 32 cases of mediastinal fibroma in the world literature. Harper,[2] in 1939, was able to find only 9 recorded instances of intrathoracic fibroma arising from the chest wall.

Intrathoracic fibromas may arise from the structures of the mediastinum or from any tissue of the thoracic wall or vertebrae. In many instances it is difficult to determine whether an intrathoracic tumor arises from the mediastinum or the chest wall, particularly when the growth is large and is adherent to both these structures.

We wish to report the successful surgical removal of a rather unusual benign tumor of the chest wall in that it was both intrathoracic and extrathoracic in location, its origin was undoubtedly from the chest wall, and it exhibited a propensity for very rapid growth during the period of gestation.

REPORT OF A CASE

A 27-year-old housewife first presented herself at the out-patient clinic in April, 1948, complaining of a slightly tender swelling beneath the left clavicle which was first noticed about two months previously. Since that time it had increased slightly in size and caused very little discomfort. Physical examination was completely negative except for a slight swelling beneath the medial portion of the left clavicle which was firm, seemingly fixed to the chest wall, and slightly tender to touch. Roentgen examination of the chest showed an unusual soft tissue shadow present along the left parasternal border anteriorly in the situation of the first and second rib costocartilages on the left side. The mass had a clear-cut border and appeared to be within the thoracic inlet. The right lung field was clear. Tomographic studies at the same time reported a mass unquestionably separate from the mediastinum. Its position was immediately posterior to the first and second rib costocartilages.

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Received for publication Sept. 22, 1949.

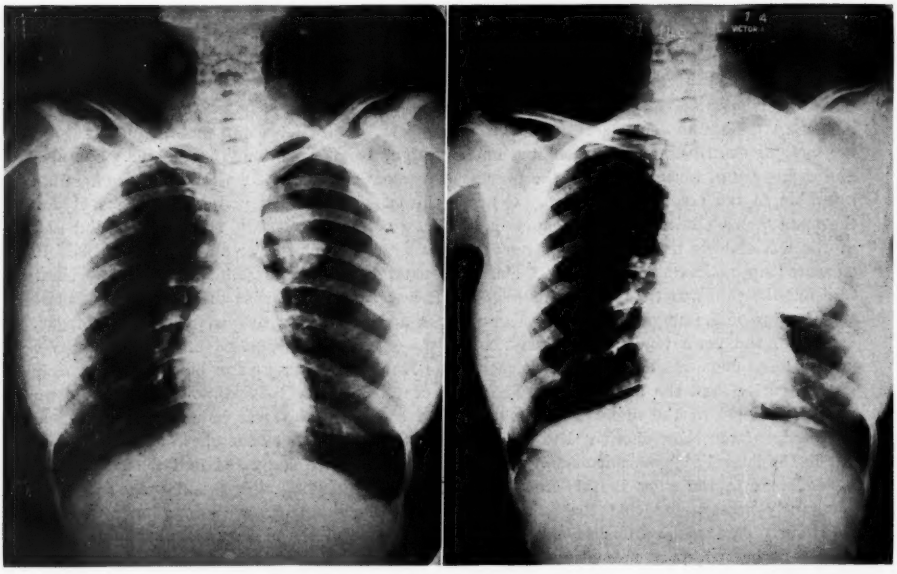
In its superior and lateral portions it faded out but appeared to be more dense medially and inferiorly. The two lateral projections indicated a considerable tumefaction within the chest wall extending posteriorly from just behind the costocartilages. A possible chondroma or primary neoplasm of the chest wall was diagnosed radiologically.

One month later, in May, the patient was admitted to the hospital for the purpose of biopsy to determine the exact nature of the growth. On admission, her complaints were the lump as described, constipation, and undue fatigue for the previous two months. She also gave a history of amenorrhea for the previous two months. She had no particular complaints referable to the respiratory system. General physical examination was negative except for the mass which clinically was situated in the anterior chest wall just below the medial end of the left clavicle and lateral to the sternal border overlying the first and second ribs. It measured approximately 5 by 3 by 1 cm. The mass was firm and solidly fixed to the chest wall but the skin was freely moveable over it. It was slightly sensitive to palpation. Clinical examination of the lungs was entirely negative. In addition, her breasts were slightly enlarged, engorged, and more tender than usual and pelvic examination disclosed an enlarged gravid uterus. The urine examination was negative, the Kahn and Wassermann blood serology tests were negative, and the hemoglobin was 74 per cent. In order to further clarify the intrathoracic portion of the tumor a pneumothorax of 600 c.c. of air was induced and roentgenray study of the chest showed that the mass was firmly related to the chest wall anteriorly, but in the lateral view no pneumothorax line was visible, which suggested that the lung might be adherent to the mass in this area. The association of lung tumor and pregnancy concomitantly necessitated that the possibility of a chorioepithelioma with lung metastasis be ruled out. This was excluded to our satisfaction by assay of the urinary gonadotropins which were reported within a normal range. A punch needle biopsy of the tumor on pathologic section failed to show any tumor cells. A direct biopsy was then carried out. At that time the tumor mass was found to be well encapsulated and a small wedge of tissue submitted for pathologic study showed a fibroma which was not histologically malignant, but the pathologist warned that such a lesion is often progressive, locally invasive, and may readily become more active.

The nature of the tumor was explained to the patient and surgical excision was advised. However, she was extremely anxious to carry her pregnancy through to a successful termination, so much so that she insisted and a compromise was reached whereby the progress of the tumor was followed by monthly examinations until her pregnancy was completed, at the end of which time she was to be readmitted for surgical extirpation. On Dec. 22, 1948, she was delivered of a normal, healthy, female child with no pre- or postnatal complications (Figs. 1 and 2).

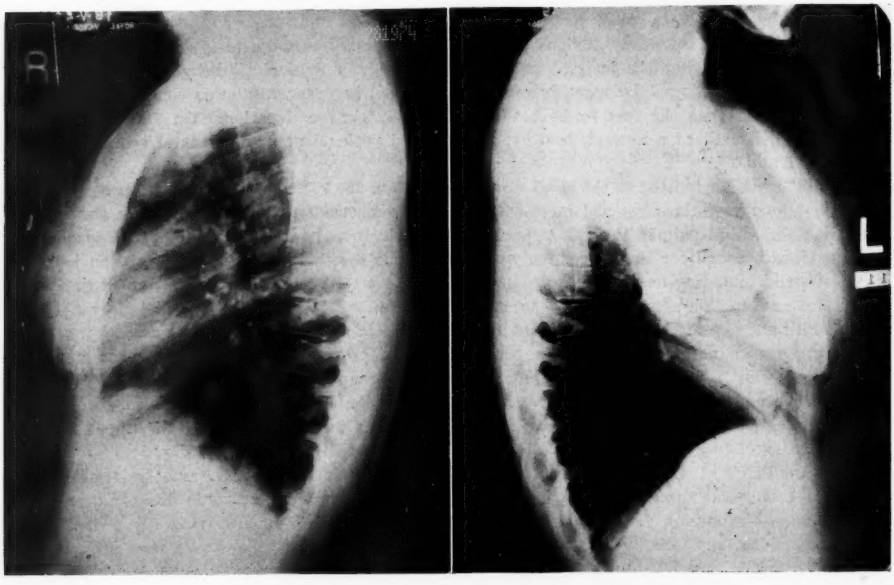
She was readmitted to the surgical service on Jan. 29, 1949. During the last two months of her pregnancy the mass had increased in size very markedly. On this admission she complained of a dull pain in the left upper chest posteriorly and in the left axilla, a nonproductive ticklish cough for the past three weeks, and some shortness of breath on exertion. The most striking finding on physical examination was the mass itself which had increased greatly in size and on this admission now measured 10 cm. in the vertical diameter and 8 by 8 cm. in width and depth. The urine examination was negative and the hemoglobin was 82 per cent. Roentgen examination of the chest reported a marked progression since the last examination demonstrating a large soft-tissue tumor mass now occupying the space of the left upper lung lobe and obliterating the latter and now also probably involving the left lung root as well as extending through the thoracic wall. The mass completely masked the upper mediastinum extending from the apex to the level of the fourth rib anteriorly (Fig. 3).

On Feb. 4, 1949, under general intratracheal nitrous oxide and ether anesthesia, excision of the tumor was successfully carried out. A transverse incision was made directly over the tumor mass extending from the left lateral border of the sternum overlying the second rib to the midaxillary line. The skin flaps were freed upward and downward for retraction. The pectoralis muscle groups were stretched tightly over the mass and these were divided in the direction of their fibers and retracted. The tumor mass then presented directly. It appeared to be well encapsulated and was of soft consistency, with some areas of firmness.



A. *B.*

Fig. 1.—Roentgenograms taken on the patient's initial visit (*A*) and thirty-seven weeks later (*B*) just prior to operation, show the marked progression of the tumor mass radiologically. *A*, A soft tissue mass is visible behind the costocartilages of the first and second ribs and *B*, it has completely masked the upper mediastinum and the left upper lung field.



A. *B.*

Fig. 2.—Lateral projections corresponding to the posteroanterior views in Fig. 1 show the progression and further clarify the localization of the mass. *B*, the tumor mass may be seen extending through the chest wall.

As near as could be identified positively it appeared to be coming through the chest wall between the first and second ribs, where it narrowed down at its exit and thus presented the shape of an hourglass. Exposure of the tumor mass was gradually accomplished by freeing the muscles and dividing the pectoralis minor. It was necessary to remove the first,

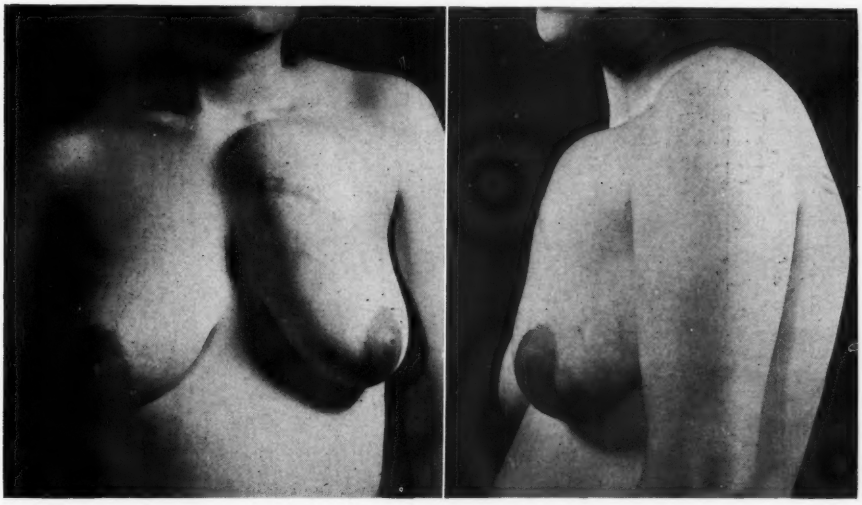


Fig. 3.—Views of the patient with the tumor in situ below the left clavicle. The scar of the previous biopsy is visible.

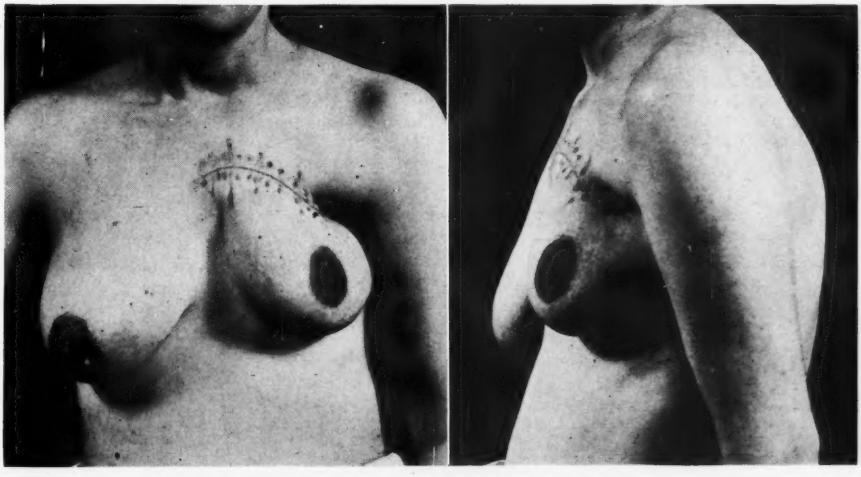
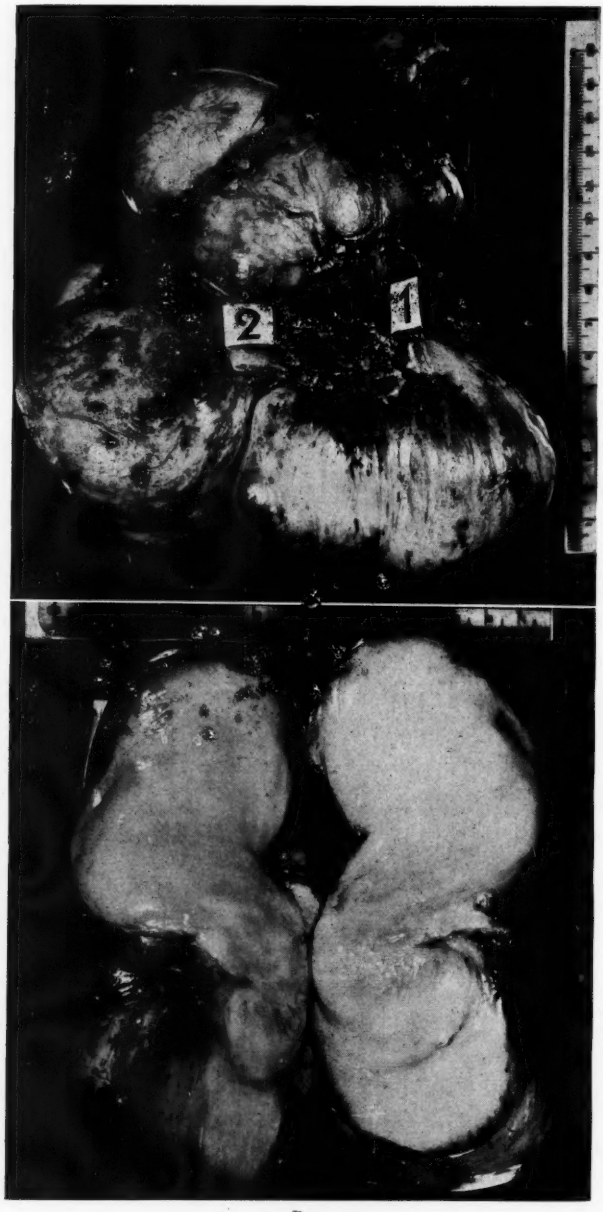


Fig. 4.—The postoperative appearance ten days after removal of the tumor.

second, third, and fourth ribs from their costochondral junctions laterally to the midaxillary line. The pleural cavity was entered and it was then seen that the tumor was relatively free from adhesions with a smooth glistening capsule and the lung was not involved nor adherent but had been merely collapsed through extrinsic pressure. The mass was gradually

A.



B.

Fig. 5.—*A*, The lobulated tumor as it appeared after excision. The isthmus of the tumor lies between the two short segments of the ribs (*1* and *2*) left attached to the specimen. The larger intrathoracic portion lies below the isthmus and the extrathoracic portion above. *B*, The tumor cut longitudinally between the rib segments through the isthmus shows its dense white homogeneous appearance.

delivered and eased through the wound in the chest wall. At this point it was seen to be adherent to the superior mediastinum at its medial edge and in order to free these adhesions it was necessary to return the tumor to its original position within the chest and to dissect the medial portion free from the mediastinum. It was then delivered again, a few of the remaining adhesions were severed, and the tumor mass was removed in toto with a small segment of the first and second ribs left attached on each side of its exit from the chest. About two-thirds of the tumor was within the chest cavity. The problem of closing the large defect in the chest wall then arose. One rib that had been removed was replaced, spanning the defect in its mid-portion and was held in place by two wire sutures passed through holes bored in the ends of the ribs. The pleura was then closed gradually by picking it up from each edge of the chest wall and mediastinum, the muscles were sutured over the defect and to the rib that spanned the gap to prevent collapse of the chest wall. The remainder of the wound was closed in the usual manner and chest drainage was obtained by a large rectal tube inserted through the seventh interspace in the midaxillary line.

Fig. 6.—The histologic pattern of the tumor made up almost exclusively of spindle-shaped cells in loosely packed collagen fibers coursing in all directions.

Postoperatively the course of the patient was relatively uneventful. Immediately after operation she developed a mild transient shock which responded readily to whole blood transfusion under pressure. For the first eight hours postoperatively the patient experienced some dyspnea with cyanosis and plethora of the face and neck which was attributed to mediastinal shift. This was completely gone by twelve hours after operation. Nasal oxygen was instituted for twenty-four hours postoperatively and then discontinued. A moderate fever persisted for the first five days when it subsided to normal. During the first ten days the patient received 200,000 units of crystalline sodium penicillin intramuscularly twice daily. Continuous Wangensteen chest suction was carried for forty-eight hours, at the end of which time the chest tube was removed. Periodic check roentgenograms of the chest showed a gradual reexpansion of the entire left lung with only a small amount of fluid at the left

base and good aeration of the entire lung just before discharge. The operative wound healed well and the chest wall showed good stability. The patient was discharged home on the fourteenth postoperative day (Fig. 4).

The specimen submitted for pathologic study consisted of a lobulated, smooth, encapsulated, dumbbell-shaped mass weighing 850 Gm. presenting two short segments, of ribs on either side of its isthmus which measured 3 by 2 cm. The portion of the tumor extrinsic to the chest cavity measured 8 by 8 by 7 cm. and the intrathoracic portion measured 8 by 11 by 18 cm. When cut it revealed a smooth yellow-white surface bulging above the cut edge. It was homogeneous in appearance except for a few scattered areas of myxomatous degeneration. Microscopically the sections showed a relatively homogeneous tissue made up almost exclusively of slender spindle-shaped cells. They coursed in all directions except for an occasional area which showed a slight tendency toward fasciculation and in which the cells were more closely compact. All cells had a scanty cytoplasm and lay in loosely packed collagen fibers. No mitotic figures were seen and a well-developed fibrous capsule was present. The pathologic diagnosis was a fibroma of the chest wall which the pathologist considered histologically benign and well encapsulated but which possessed considerable growth potential (Figs. 5 and 6).

COMMENT

Benign tumors of the chest wall possess the features of all benign tumors in any portion of the body, that is, they are encapsulated and lack the invasive properties of malignant lesions. Tumors of the chest wall, because of their location, are especially suited to diagnostic biopsy as a preliminary to treatment or a planned surgical excision.

The differential diagnosis between benign and malignant tumors in this location is a prerequisite to intelligent treatment. Secondary metastases to the chest wall from an unsuspected primary source will modify or alter the treatment altogether. The establishment of a benign lesion calls for early surgical extirpation. Any tumor which has remained dormant for a long time and suddenly has begun to grow rapidly should be considered as probably malignant. The frequency with which these benign tumors become malignant is the most pressing indication for their early surgical removal. In addition, benign tumors, if neglected, may become so large that their removal is rendered unnecessarily hazardous.

Provided that the tumor is suitably located punch biopsy by means of the biopsy needle may be carried out, but there are many who object to this procedure from the standpoint of spread of malignant cells. The core of tissue obtained is often so small and fragmented that many pathologists prefer not to make a histologic diagnosis on the specimen submitted. Direct biopsy with excision of an adequate wedge of tissue for histologic study is to be preferred.

Tumors may arise from the chest wall and project into the pleural cavity without having any visible or palpable portion that can be observed clinically. In these cases exploratory thoracotomy is the only remaining diagnostic procedure that can be offered and in addition will provide the only definite answer as to the operability of the growth. In such cases the surgeon may submit a biopsy to the pathologist for an immediate histologic diagnosis by the quick frozen section technique and if the tumor is reported to be benign or a primary malignancy of the chest wall complete surgical excision should be carried out at

that time. Exploratory thoracotomy is now fortunately almost as safe as abdominal exploration and need not be regarded as too dangerous to be warranted as a diagnostic procedure.

The benign tumors arising from the thoracic wall may be classified as follows:

1. Chondroma
2. Fibroma
3. Osteoma
4. Myxoma
5. "Benign" giant cell tumor
6. Angioma, hemangioma, lymphangioma, etc.

From a surgical standpoint the cases of benign tumors of the thoracic wall, whether they have an intrathoracic portion or not, are most gratifying. The risk is not great if the tumors are removed before their size alone adds many unnecessary hazards to the operation. The margin of respiratory safety in patients with large tumors exerting extrinsic pressure on the lung and other vital intrathoracic organs is extremely narrow and most of the effective aeration of the blood in the pulmonary system is accomplished through only one lung. In the period during which the tumor undergoes its insidious growth, adjustments to diminished vital capacity, pressure on the large vessels, and altered intrathoracic dynamics are made. Removal of the tumor completely upsets this compensatory equilibrium and the immediate postoperative period may be complicated by sudden alterations in the circulatory and respiratory systems. Such alterations, we believe, accounted for the cyanosis and dyspnea in the immediate postoperative period in the case presented. Early surgical extirpation, therefore, is to be strongly recommended before the development of any of these deleterious factors.

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FAMILIAL INCIDENCE OF CERVICAL RIBS

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WICHITA, KAN.

ALTHOUGH the occurrence of cervical rib (or ribs) is relatively common, about ½ per cent according to some studies, in that portion of the literature on cervical ribs which we have had an opportunity to examine the familial tendency is rare. Thompson,[1] in 1908, reported a family of five generations in which seven out of sixty-four members were affected with atrophy of the hand muscles. It was his opinion that this was due to cervical ribs. He had only two members of the family examined roentgenographically and they both showed cervical ribs, so it is not entirely conclusive. Weber[2] presented a case of cervical ribs with atrophy of the hand muscles in which a brother and sister had asymptomatic, bilateral cervical ribs. Other authors[3, 4] have discussed the embryology and comparative anatomy and have given theories to account for the formation of cervical ribs. These features will not be discussed here.

HISTORY

H. W., a white man of German extraction, aged 46 years, was first seen in the Sedgwick County Hospital and Clinic in April, 1947, complaining of cough, weight loss, hemoptysis, and general malaise. Tuberculosis was suspected and a chest film ordered. This showed a minimal fibrotic process, probably tuberculous, involving both apices. An incidental finding was a cervical rib on the right. His father was alive but refused to be examined.

TABLE I

RELATION	AGE (YR.)	DATE OF ROENTGENOGRAM	SIDE OF RIB	OTHER ANOMALIES
Father	46	April, 1947	Right	Sacralization of fifth lumbar vertebra
Mother	42	Sept., 1947	Left	Ununited transverse process first lumbar vertebra, left
Son	1	Sept., 1947	Bilateral	Transitional fifth lumbar vertebra
Daughter	4	Sept., 1947	Bilateral	Posterior neural arch defect in transitional fifth lumbar vertebra
Daughter	7	Sept., 1947	Bilateral	Sacralization of fifth lumbar and neural arch defect
Son	8	Sept., 1947	Bilateral	Sacralization of fifth lumbar vertebra
Daughter	12	Sept., 1947	Bilateral	Transitional fifth lumbar vertebra and neural arch defect
Son	16	March, 1948	None	Spinal bifida occulta
Daughter	20	Feb., 1949	None	None
Daughter	21	April, 1949	None	None
Daughter	22	Feb., 1949	None	None
Daughter	25	Feb., 1949	None	None
Daughter	27	None		
Granddaughter	4	Feb., 1949	None	None

Received for publication Oct. 5, 1949.
From the Chest Clinic of the Sedgwick County Hospital and Clinic.

The patient's wife, of Irish and German parentage, and eleven children had always been in good health. One child died at 17 years of age of a ruptured appendix. The family had routine x-ray examinations of the chest because of possible tuberculous contact. The numerous cervical ribs were ob-

Fig. 1.

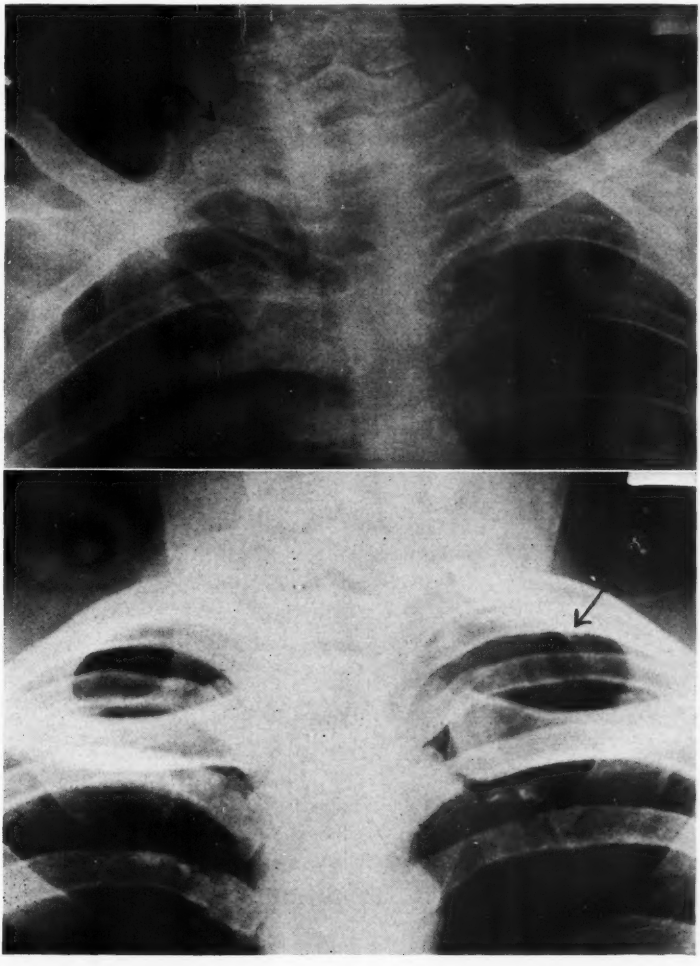


Fig. 2.

Fig. 1.—H. W. (father), aged 46 years.
Fig. 2.—A. W. (mother), aged 42 years.

served and further studies made. There are four grandchildren, but the only one who was examined roentgenographically had no cervical ribs, so it is not possible to trace the familial tendency beyond the first generation. This is summarized in Table I and shown in Figs. 1 through 7.

The possibility of rudimentary first ribs as ruled out by having x-ray films of the entire spine. In this manner twelve ribs could be counted on one side and thirteen on the other in the mother and father. The children who were affected had thirteen bilaterally. As Table I shows, each member of the

Fig. 3.

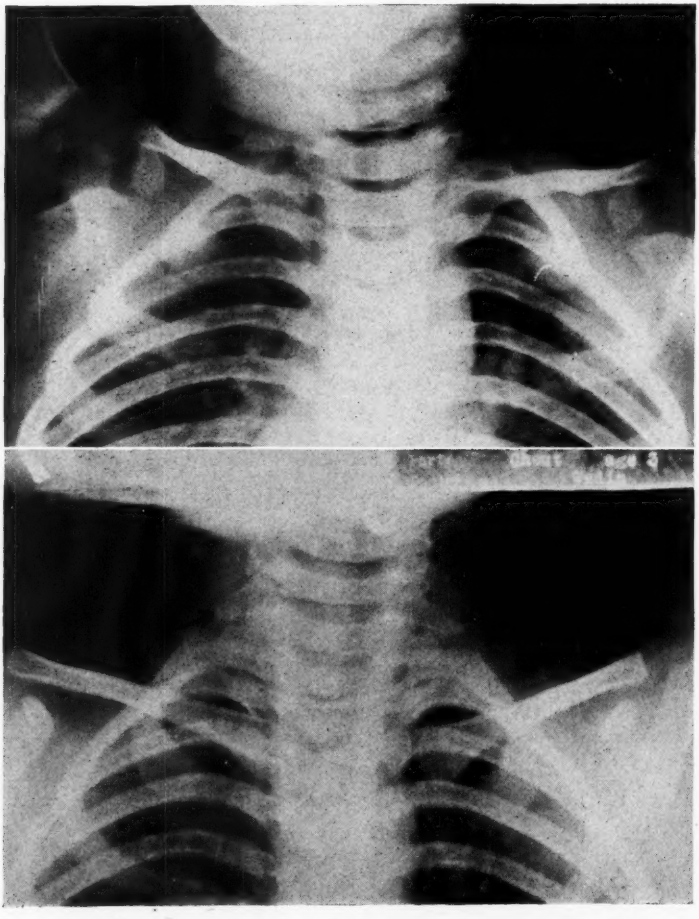


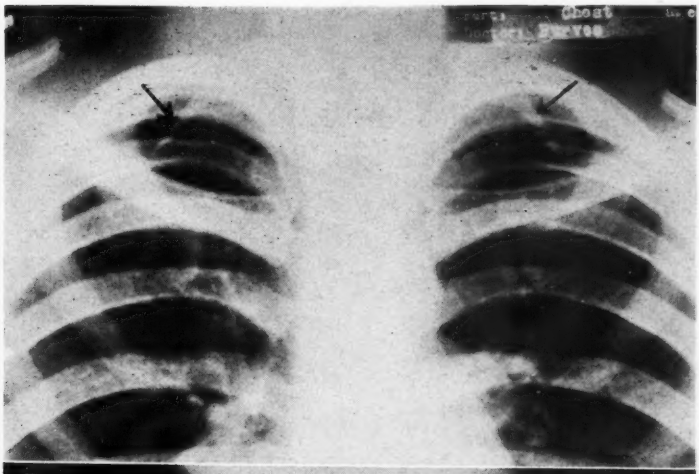
Fig. 4.

Fig. 3.—W. E. W. (son), aged 1 year.
Fig. 4.—K. W. (daughter), aged 4 years.

family having cervical rib also has some other anomaly of the spine. There are no gross anomalies outside the vertebral column. Adson[4] and Bassoe[5] have mentioned other anomalies as a frequent occurrence in cases of cervical rib. There is no scoliosis in any of these cases even though this is reported by Hadley as frequently associated with cervical ribs, particularly if unilateral.

It is interesting to note that the father has a right unilateral rib and the mother a left unilateral rib and all of the children with cervical ribs have them bilaterally. In the young children we looked specifically for the rudimentary ribs because they may have easily escaped detection. If, as is thought, growth

Fig. 5.



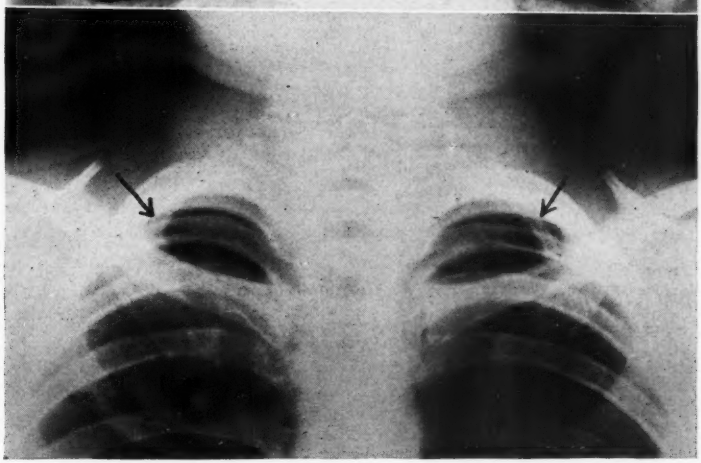


Fig. 6.

Fig. 5.—N. W. (daughter), aged 7 years.
Fig. 6.—E. W. (son), aged 8 years.

occurs from an epiphysis at the apex of the rib, then these rudimentary ribs in the children will probably continue to enlarge and elongate.

Even though the father and all adult members of the family make their living by housework or unskilled labor, none of them have had any symptoms

referable to their spinal column or the cervical ribs. According to Adson[4] 55 per cent of all cervical ribs are asymptomatic.

It is unfortunate that we are not able to trace this family through previous and subsequent generations so that a more accurate study of the familial tendency can be made. However, if this tendency is kept in mind other cases will no doubt be uncovered and a more complete study made.

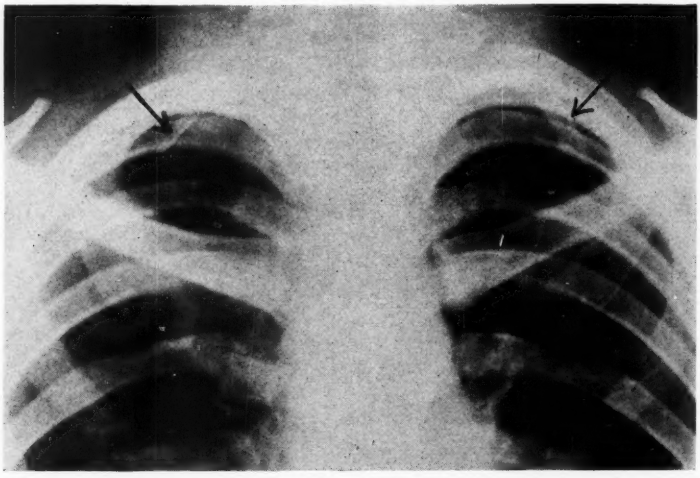


Fig. 7.—M. W. (daughter), aged 12 years.

CONCLUSION

A family is presented in which the father and mother and five of ten children examined roentgenographically had cervical ribs. The familial incidence of cervical ribs is discussed.

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ANOMALOUS ARTERIES TO THE LUNG ASSOCIATED WITH CONGENITAL PULMONARY ABNORMALITY

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THE concept of pulmonary sequestration[1] or bronchopulmonary dissociation associated with anomalous arteries from the aorta to the lower lobes of the lungs has been discussed adequately in the literature by Pryce and associates.[1, 2] Two other papers, one by McCotter,[3] in 1910, and another by Douglass,[4] in 1948, complete the list of rather detailed studies on this subject. In view of the surgical importance of this condition and pathologic interest in it, we wish to review the subject further, add 5 cases of our own, 1 of which already has appeared in the literature,[5] and draw attention to the report of an interesting case by Rosenthal[6] which tends to strengthen the concept of sequestration as advanced by Pryce.[1]

The first reported case of an anomalous artery which arose from the aorta and supplied the lung was described in the literature by Huber[7] in 1777. Since then only 7 other cases[3, 8-13] have been reported from necropsy. Even if those cases were added in which additional vascular abnormalities[14-16] were present, the total would be only 11 cases in which the abnormality was found at necropsy. The first surgical report appeared in 1940.[17] In the last ten years a total of 26 surgical cases has been reported.[1, 2, 4, 5, 17-25] In 3 of the 26 surgical cases, the operations ended fatally because of hemorrhage from the anomalous artery.[4, 17, 22]

Bronchopulmonary sequestration as here defined is limited to a lower lobe of a lung, usually the left. The lobe is found to contain a bronchiogenic cyst or cysts, or a system of bronchi which does not communicate with the normal bronchial tree. Usually a large part of the lobe consists of tissue which has never been aerated. This sequestered area is supplied by a large artery which derives from the lower thoracic or upper abdominal aorta or from the celiac axis. The anomalous artery, during embryonic life, caused the sequestration of the segment of pulmonary tissue in the lower lobe.[1, 2]

EMBRYOLOGY

Normal Development of the Pulmonary Arterial System.—Aeby[26] was the first to formulate the conception that the vascular system originates as an indeterminate network of capillaries. The definitive circulation consists of those channels of the network which remain permanently in use. Theoretically,

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Abridgment of thesis submitted by Dr. Bruwer to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Radiology.

Received for publication Oct. 6, 1949.

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the persisting vessels can take practically any course and have any connections that could be traced in the original network. But in actuality the final pattern is usually rather uniform. What actually determines the differentiation of some channels into veins and some into arteries is unknown.

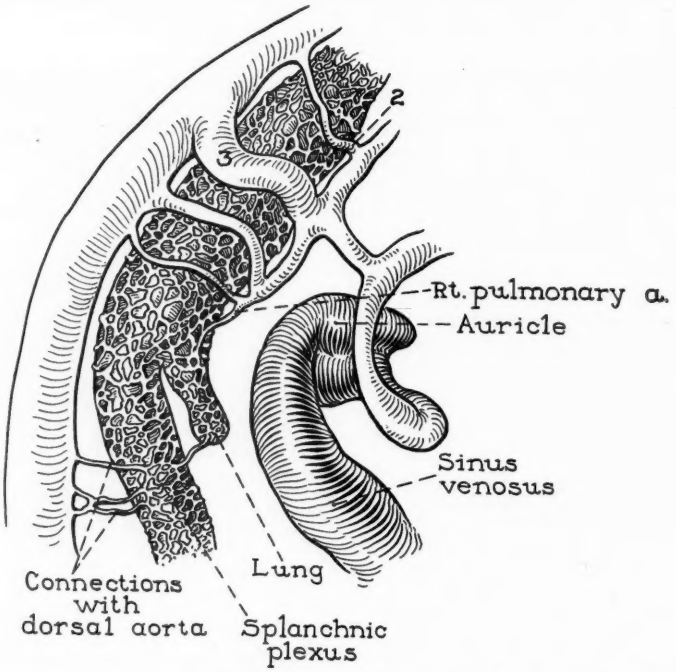

Fig. 1.—Approximately the 4 mm. stage of the foregut which shows the normally developing pulmonary artery and also a few of the connections of the splanchnic plexus with the dorsal aorta; these latter usually atrophy. When they persist and maintain a connection with the pulmonary anlage, an anomalous artery results. Pulmonary venous drainage has been omitted deliberately.

The plexus which concerns this discussion (Fig. 1) is the capillary plexus which embraces the primitive gut, and particularly that part of it in the region of the foregut where the pulmonary anlage develops.[27-29] This plexus as a whole is the so-called splanchnic plexus of capillaries. It has connections with the dorsal aorta. When the lung bud appears on the ventral surface of the foregut, it carries part of the splanchnic plexus with it. This is the part of the splanchnic plexus which Huntington[30] has called the "postbranchial pulmonary plexus." Normally the primitive pulmonary arteries, which develop as angioblastic buds from the region of the aortic sac,[29, 31, 32] inosculate with the plexus on the lung bud. The connections with the dorsal aorta then atrophy.

The Anomalous Artery.—Fig. 1 indicates that if one connection or more between the dorsal aorta and the postbranchial pulmonary plexus persists, one or more anomalous arteries to the lung will result.

Normal Development of the Respiratory Tree.[33]—The earliest evidence of the future respiratory tree, the lung bud, is manifest when the foregut measures about 3 mm. The laryngotracheal groove appears in the floor of the foregut just caudal to the pharyngeal pouches. The more caudal end of this anlage gives rise to the lung bud, which begins to bifurcate at about the 4 mm. stage, thus forming the primary bronchi. By further budding the plan of the final pulmonary lobes is already evident at the 7 mm. stage. By the 10 mm. and 14 mm. stages, secondary branchings of the bronchi are defined.

Sequestration of Pulmonary Tissue.—The size of the sequestered mass will depend on the embryologic stage at which sequestration occurred. For instance, sequestration at the 4 mm. stage is likely to produce agenesia of a lung, but sequestration at the 14 mm. stage will probably affect only a lobe or portion of a lobe.

In an attempt to give a reasonable explanation for bronchopulmonary sequestration, Pryce examined the theories regarding the origin of lower accessory lungs. He termed the latter condition "extralobar sequestration," and the former "intralobar sequestration." In both conditions a branch from the aorta supplied the sequestered tissue. In the accessory theory lower accessory lungs are regarded as developments which result from the potentiality of some parts of the foregut to give rise to respiratory tissue. The blood supply from the aorta would be a secondary result of their development. According to the fraction theory, sequestration takes place through such mechanisms as (1) amputation by the developing aortic arch, (2) closure of the pleuroperitoneal iter, (3) deepening of pleural fissures, or (4) by embryonic adhesions. The sequestered tissue, it is said, would then acquire a blood supply in its new situation. This view conforms to the ideas of Beneke[34] who stated that a displaced organ easily acquires a blood supply from the region in which it lies in the embryonic body.

However, neither of these theories can be accepted, because in both the blood supply from the aorta is regarded as a factor which is secondary to the existence of the sequestered pulmonary tissue. But, in true fact, an anomalous artery from the aorta sometimes supplies blood to normally connected pulmonary tissue, in which case it cannot possibly be regarded as a secondary event.[15] This is the basis for Pryce's view that the anomalous artery, while developing, may produce sequestration of a portion of pulmonary tissue.

Rosenthal's case suggests that such an anomalous artery may cause sequestration of a portion of the lower lobe, and then itself become separated from the aorta. This case seems to supply the "missing link" between those cases of sequestration obviously associated with an anomalous vessel and those cases of development or congenital cysts of the lung in which an anomalous vessel is not evident (Fig. 9).

PATHOLOGIC ASPECTS OF INTRALOBAR SEQUESTRATION

Sequestered Pulmonary Tissue.—The classification suggested by Pryce as to the gross types of tissue encountered in intralobar sequestration, is as follows: (1) a large cyst in the sequestered area, (2) a polycystic mass, and (3)

a sequestered mass which contains bronchi that branch parallel to the artery. Furthermore, in any of these gross types the bronchial or cystic elements may be completely dissociated from the normal bronchial tree or in some communication with the bronchial tree, usually the result of infection or suppuration.

Infection of the Sequestered Lung.—Various authors[1, 5] have drawn attention to the fact that the area of lung supplied by an accessory artery coming off the aorta, is supposedly nonfunctioning. Clagett and McDonald[5] speculated as to whether or not such a nonfunctioning area would be more likely to become infected than pulmonary tissue which is in physiologic balance. The present views as to the pathology of the sequestered cystic area would not seem to substantiate their speculation as to the cause of infection. In addition, experimental work of Levy and Blalock[35] opposed such a mechanism. They transplanted the proximal cut end of the left subclavian artery of mature dogs into the distal cut end of the left pulmonary artery. Although the quantity of oxygen consumed by the lung was found to be small under resting conditions, the lung did remain functional as was proved by increased uptake of oxygen during anoxemia. Respiratory movements on the involved side remained normal. After several months neither the involved pulmonary artery nor the affected lungs showed any noteworthy microscopic alterations. The pressures only a short distance beyond the anastomoses were only one-half those in the systemic arteries.

It would seem that sequestered pulmonary tissue could become infected in various ways: 1. In cases in which there is some communication with the normal bronchial tree, infection could occur via such a communication. 2. In cases of complete sequestration, infection might take place by one of two obvious ways. It might result from direct spread by way of the tissues from an infected, normally connected lung or from hematogenic spread. Pryce and associates[2] presented an excellent example of the latter in which pulmonary symptoms soon followed osteomyelitis of the femur.

Our report deals primarily with cases of sequestration in which the anomalous artery was the only vascular anomaly in evidence.

Side Involved.—In 18 of the cases reported in the literature the anomalous arteries were on the left and in 10 on the right. One case was that of bilateral arteries; in 5 cases the side was not known.

Type of Artery.—A glance at the titles of articles on the subject will show that most authors write about the anomalous arteries as pulmonary arteries. This cannot possibly have a functional meaning, as pulmonary arteries carry venous blood to the lungs. Calling them "pulmonary" arteries can only indicate that they are arteries going to the lungs. Natucci,[15] in his interesting case of bilateral anomalous arteries in which there was an associated patent ductus arteriosus but in which the lungs were normal, described them as bronchial arteries. Pryce found the anomalous arteries to be histologically more like pulmonary arteries in that they were elastic rather than like systemic arteries which are muscular.

Diameter of Artery.—The diameter of the vessels varied from 2 mm. to 1 cm., and they averaged about 5 mm.

Degenerative Changes in the Artery.—In 5 cases from the literature degenerative changes such as atheroma or medial calcification were mentioned. These changes may be related to the age of the patient and to sepsis.[1] The observation by McDonald and others[36] that nonfunction tends toward endarterial changes in vessels supplying a nonfunctioning area would seem to be applicable in cases of bronchopulmonary sequestration when endarteritis is found.

Distribution of Anomalous Artery.—Although an anomalous artery may supply a normal lower lobe, reports indicate that it usually is associated with sequestration of pulmonary tissue.

INCIDENCE OF ANOMALOUS ARTERIES

Anomalous arteries unassociated with any other vascular anomaly have been reported at necropsy in 8 cases and at the time of operation in 26 cases. Knowledge of 9 other cases[37] and the addition of 4 new cases in this report makes a total of 47 cases. We are aware of a few additional cases in which other anomalies were associated, but we will not discuss these in this paper.[14-16]

TABLE I. AGE OF PATIENTS AT ONSET OF SYMPTOMS AND AT OPERATION AS REPORTED IN THE LITERATURE

AGE (YR.)	NUMBER OF CASES	
	AT ONSET OF SYMPTOMS	AT OPERATION
0 to 9	6	3
10 to 19	7	7
20 to 29	1	5
30 to 39	0	2
40 to 49	0	2
50 to 59	1	1
Total*	15	20

*The discrepancy in totals is due to the fact that in 5 cases the age at onset of symptoms was not mentioned.

At one institution the incidence of anomalous arteries to the lung is reckoned at almost 2 per cent of all pulmonary excisions.[38] In the reported cases in which details were given, 15 patients were men and 11 were women, and the sex of 8 is not known. In the surgical cases it often was possible to discover the age at which symptoms first occurred as well as the age at which operation was performed. Table I indicates the distribution in various decades. It is obvious in this small series of cases that the onset of symptoms usually occurred within the first two decades of life. In the 15 cases in which the age of onset was known, the average delay before operation was four years. The shortest period was six months and the longest delay was twenty-one years.

CLINICAL ASPECTS

Symptoms.—The commonest symptoms referred to are productive cough, which becomes aggravated at intermittent periods, fever, pain, and chills.

Diagnosis.—Diagnoses frequently made are pneumonia, empyema, and bronchiectasis. Roentgenograms usually indicate cystic conditions or bronchiectasis. Bronchography was mentioned in 7 cases in the literature. Of these, 2 patients showed bronchiectasis by this method of examination. It is of interest that the other 5 patients did not show evidence of connection between the pathologic area and the bronchial tree.

Bronchoscopy will often reveal a purulent discharge into the bronchi of the lower lobes. If other findings suggestive of sequestration are noted, the latter feature may be reckoned as additional evidence.

Studies of Sputum.—Kirklin[39] has pointed out that active tuberculosis is an associated condition in not more than 5 per cent of cases of congenital cysts of the lung. In none of the cases of sequestration of the lower lobe has such a finding been reported.

In view of the fact that a small percentage of bronchiogenic cysts become malignant, the possibility of finding malignant cells in the sputum of patients having sequestration must be borne in mind.

The conditions most commonly entering into the differential diagnosis are acquired bronchiectasis, pneumonia and bronchopneumonia, empyema, and diaphragmatic hernia.

Treatment.—Antibiotic substances such as penicillin and sulfonamide drugs may temporarily improve the acute febrile conditions of the patient. An incorrect diagnosis of empyema may be the cause of repeated aspirations and drainage operations, none of which will be effective in curing the patient. It is evident from the nature of the condition that only surgical extirpation of the diseased lobe can cure intralobar sequestration and its complications. Anomalous arteries are, however, an operative hazard. In 3 cases in the literature,[4, 17, 22] lobectomies which were apparently going well were fatally complicated by hemorrhage from the anomalous artery. Haight[37] warned that in operating on cystic lower lobes the surgeon should always be on the lookout for anomalous arteries.

MATERIAL AND METHODS

The pathologic material used in this study was obtained as a result of lobectomies on 5 patients at the Mayo Clinic during the years 1944 to 1949. All specimens were lower lobes which showed the presence of intralobar sequestration associated with large anomalous arteries. As stated before, 1 case has been reported previously in the literature.[5] The method of examination of tissue will be described with the observations on it.

OBSERVATIONS AND COMMENTS

The data concerning our cases are presented in tabular form (Table II).

In these 5 cases observations on the main points of interest were in agreement with those in the surgical cases from the literature. The symptoms were typical, that is, productive cough, chills, fever, and pain. All of these symptoms were intermittent as is usually true of congenital cystic disease of the

lungs. It is well to bear in mind that the presence of a sequestered, usually cystic, area does not in itself represent a manifestation of the disease. "It is suppuration that makes the disease."[40] Case 3 is a good example of this, the presence of a cyst having been a fortuitous discovery. As in the surgical cases from the literature, the patients were mainly in the younger age groups and the left side was involved predominantly. A number of wrong diagnoses both clinical and roentgenologic had been made before the correct diagnosis was derived. This was also reflected in the fact that 4 of the 5 patients had been hospitalized at some time before entering the clinic, and 2 of them had undergone unsuccessful operations.

TABLE II. DATA CONCERNING FIVE PATIENTS HAVING ANOMALOUS PULMONARY ARTERIES

	CASES				
	1	2	3*	4	5
SEX	M	F	F	F	F
Age (yr.)					
At onset of symptoms	16	27	18	5	2
At operation	17	30	21	27	34
Side	L	L	L	R	L
Relation of origin of artery to diaphragm	Above	Above	Above	Below	Above
Size of artery	1 cm.	1 cm.	5 mm.	6 mm.	7 mm.
Symptoms	Pain, cough, purulent sputum, fever, chills	Cough, purulent sputum, chills	Fever, chills, syncope, dyspnea on exertion	Cough, purulent sputum, fever	Pain, cough, purulent sputum, fever, chills, dyspnea on exertion
Pathologic group (Pryce)	Dilated bronchi	Polycystic	Large cyst	Large cyst	Polycystic

*This patient had no symptoms until after accidental discovery of cyst during routine physical examination.

Gross Pathologic and Histologic Features.—In our 5 cases the anomalous artery entered the lung in the region of the lower one-half of the pulmonary ligament, usually near the lower border of the lung and fairly far posteriorly. The distribution of the artery could be determined only sketchily in Cases 1, 2, and 3 (Figs. 2, 3, and 4). In Case 4 roentgenograms of the removed lobe after the injection of opaque oil apparently outlined its distribution accurately (Figs. 5 and 6). The anomalous artery seemed to have confined its course to the considerable portion of the lobe which was diseased, that is, sequestered. Unfortunately, the normal pulmonary artery was not injected with oil subsequently so as to determine whether or not its ramifications anastomosed with those of the anomalous artery. Such was the situation in Natucci's case of bilateral anomalous artery, in which pulmonary tissue was normal. In Case 4 subsequent cutting of the tissue into multiple slices made it possible to follow the gross distribution of the artery in the sequestered tissue, to which it seemed to remain confined (Fig. 7). In Case 5 opaque oil was

not injected into the vessels, but the injection of water into the normal pulmonary artery or the anomalous artery, revealed the presence of substantial communication between the 2 vessels, probably in the precapillary region. Multiple slices proved that the branches of the anomalous artery ran in close relationship to the walls of the cystic spaces (Fig. 8). The finding of obvious

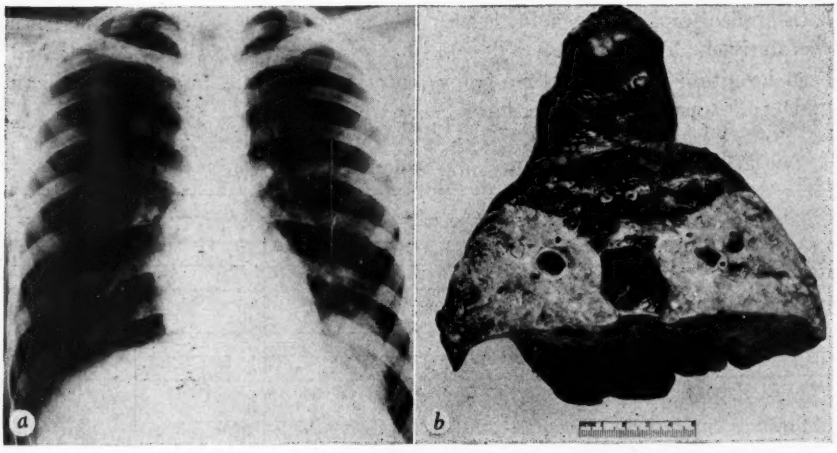

Fig. 2 (Case 1).—*a*, Opacity in the region of the left lower lobe. *b*, Gross specimen of removed left lower lobe. Sequestered part of lobe (white) contains some well-indicated dilated bronchi. These bronchi had no connection with the normal bronchial tree. Anomalous vessel was out longitudinally and can be seen near the outer edge of each half of the sequestered area.

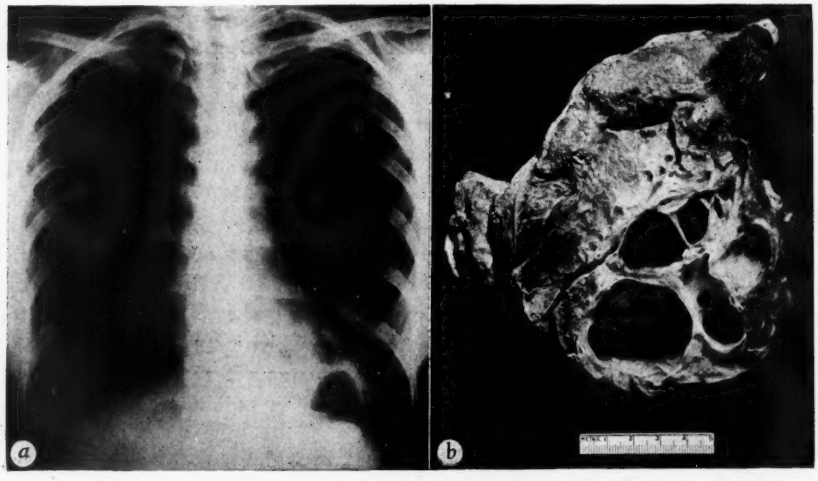

Fig. 3 (Case 2).—*a*, Multiple cystic areas shown with levels of fluid in region of left lower lobe. *b*, Removed left lower lobe in which multiple cysts are demonstrated and branches of anomalous artery can be seen distributed in the walls of the cysts.

anastomoses between the branches of the anomalous artery and those of the pulmonary artery, conformed to the findings in Natucci's case.

The question arises whether or not degenerative changes in anomalous arteries are due to pressure or to nonfunction. The anomalous artery in the case reported by Batts[8] showed medial calcification and endarteritis. The

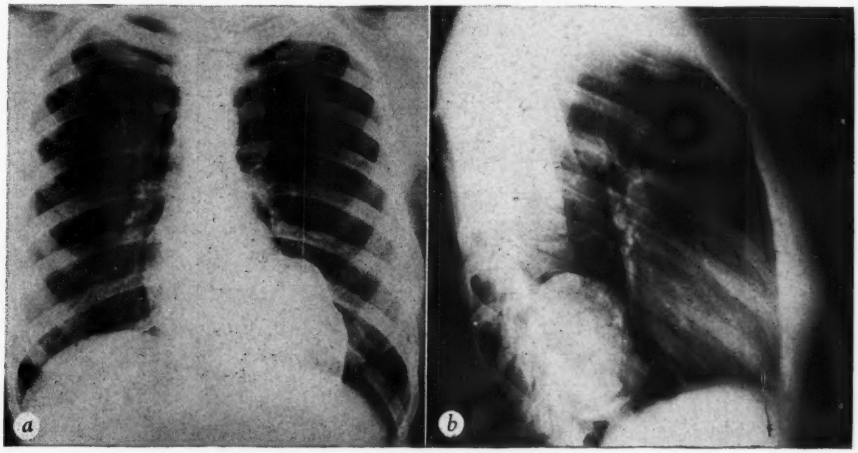

Fig. 4 (Case 3).—*a* and *b*, Unicameral cyst indicated in left lower lobe. A diagnosis of encapsulated empyema was entertained in this case. At lobectomy the involved lobe was seen to receive a large anomalous artery from the aorta.

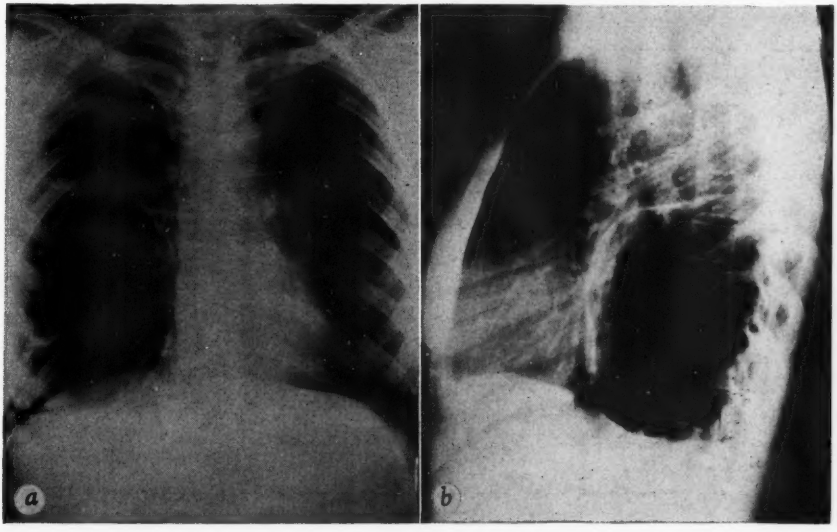

Fig. 5 (Case 4).—*a* and *b*, Large cystic area shown in right lower lobe. Patient arrived at clinic having undergone unsuccessful "drainage" operations on three previous occasions.

Fig. 6 (Case 4).—*a*, Gross specimen of right lower lobe. *b*, Distribution of radiopaque oil injected into anomalous artery which supplied the sequestered portion of the lung. *c*, Three millimeter slab of the removed lobe which indicates sequestered area. Because of the total lack of pigmentation and aeration the area appeared white. Compare this with normally aerated portions (dark).

artery supplied normal pulmonary tissue. Those areas of lung not supplied by the artery did not reveal the same changes in the vessels. It may be reasoned, as Batts reasoned, that pressure was the cause of the degenerative

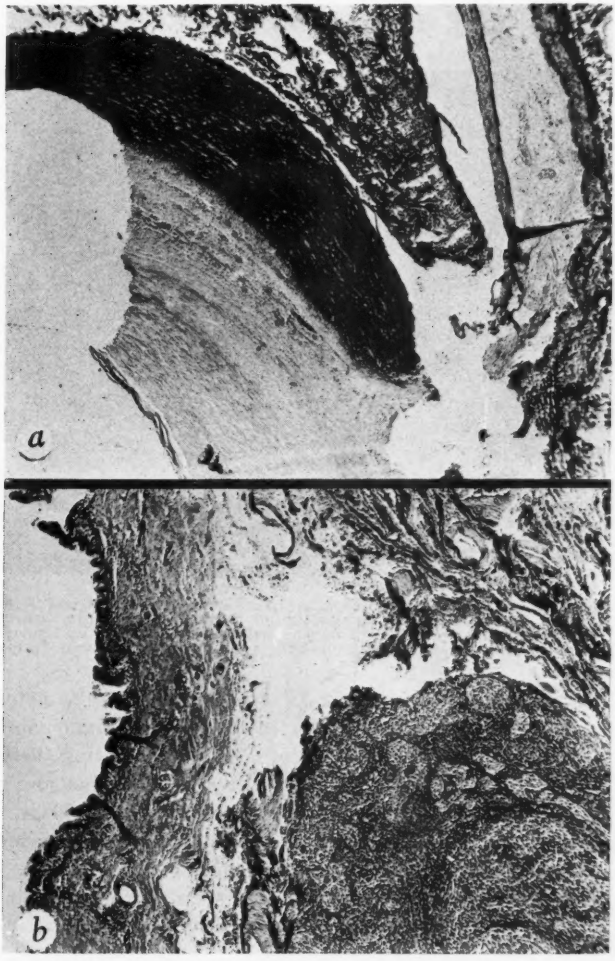

Fig. 7 (Case 4).—*a*, Anomalous vessel stained with van Gieson's stain (×35). Elastic nature of artery easily seen. Note evidence of endarteritis. *b*, Portion of sequestered lung indicating lining of cyst, and unpigmented lymph node which was situated subpleurally at entrance of anomalous artery into lobe (hematoxylin and eosin, ×35).

changes in the vessel in this case. But it may be said with equal truth that the area supplied by the artery, carrying arterial blood, was nonfunctional under average conditions of oxygen demand, and that this was the cause of the degenerative changes in the vessel. The work of Levy and Blalock discussed earlier in the paper suggested that transplanting the subclavian artery

into the pulmonary artery did not result in any great rise of pressure in the pulmonary circulation in dogs. It would, therefore, seem reasonable that nonfunction rather than pressure might have been the cause of endarteritis in Batts' case. Observations by McDonald, Harrington, and Clagett[36] tend to support this view. This is, of course, only conjecture.

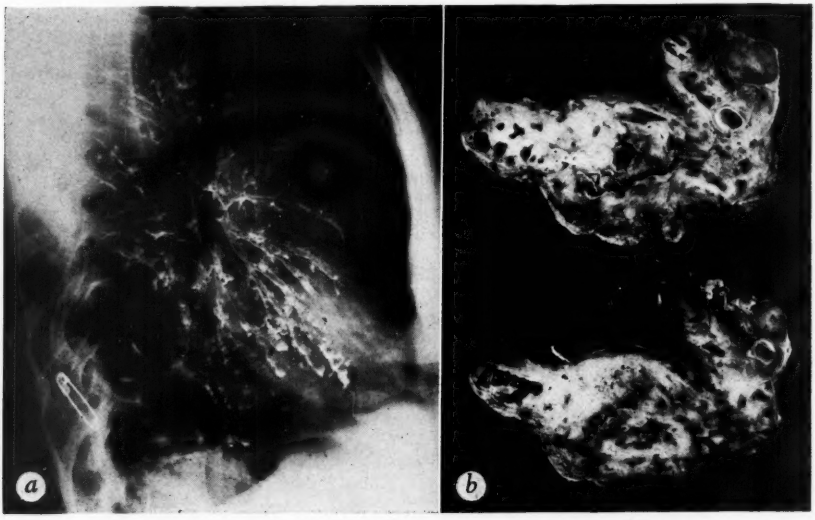

Fig. 8 (Case 5).—*a*, Left lateral bronchogram. Note posterior basal segment did not fill with opaque oil. This is the sequestered cystic area. *b*, Slabs from specimen removed at lobectomy. Note sequestered area (white) which is unpigmented and unaerated. Also, large anomalous artery and associated unpigmented, subpleurally situated lymph node.

Studies of pressure and analyses of gas by means of catheterization of the pulmonary arteries of patients suspected of having anomalous arteries to the lower lobes of lungs would be helpful in reconstructing the physiologic and hemodynamic picture in such lobes. Intravenous studies using radiopaque media with the aid of roentgenoscopy would be of further help. Moreover, after surgical removal of affected lobes, studies by means of injections of radiopaque plastic materials such as Vinylite mixed with iodoform would give accurate radiographic evidence of the structural status of the lobe, and subsequent corrosion of the specimen would leave true casts of the prevailing anatomic conditions. These factors would then be better correlated with pathology, aiding in the interpretation of histologic material. Such studies have been made in other pulmonary conditions by Lindskog[41] and his associates and would supply the necessary background for the suggested studies on sequestration.

In each of 3 cases herein described, a lymph node of fair size was found situated subpleurally in the region where the anomalous artery entered the lobe. In Case 1 evidence of pigmentation in the node was slight. In Cases 4 and 5 the nodes did not show any carbon pigmentation. In the latter two

cases this can probably be regarded as good evidence that the area of lung drained by these nodes was not at all functional, that is, it was totally sequestered. In Case 2 microscopic study revealed a few small lymph nodes in relation to the larger arterial branchings in the sequestered area. Only one of these contained a small amount of pigment. In the 2 cases in which the intact lower lobes could be studied by the multiple-slice method, it was surprising to note the large proportion of the lobe which consisted of unaerated, unpigmented tissue. This comprised possibly 70 to 80 per cent of the lobe. Shrinkage due to formalin no doubt makes this figure somewhat higher than the true condition would be, owing to aerated normal parts shrinking more than the solid and unaerated parts.

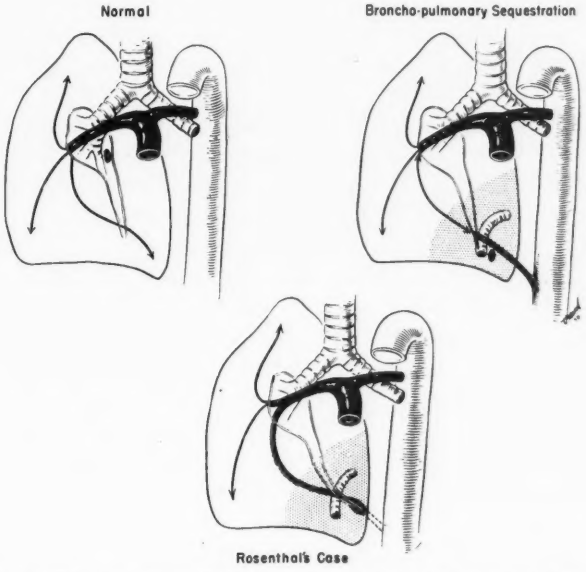

Fig. 9.—Is it possible that Rosenthal's case indicates a link between bronchopulmonary sequestration and some cases of congenital cystic disease of the lungs?

SUMMARY AND CONCLUSIONS

The concept of intralobar bronchopulmonary sequestration and its relationship to associated anomalous arteries from the aorta is a concept of cause and effect. The reasoning of Pryce that the anomalous artery is a primary factor and that in many cases in which it occurs it causes sequestration of a portion of the lower lobe is logical and is substantiated by the pathologic picture. It is a more reasonable way of regarding this condition than the argument which puts sequestration first and the anomalous vessels second.

Intralobar sequestration of itself is not a new entity. Most congenital cysts of the lung, wherever situated in its substance, may be regarded as examples of sequestration. In situations other than the lower lobes, anomalies

of vascular supply are not evident. Other causes have to be considered in these situations. There is, however, no proof that anomalies of the intrapulmonic course of the branches of the normal pulmonary artery and vein may not be causal factors.

Rosenthal's[6] case is of special interest. It suggests that many patients heretofore regarded as having only a congenital cystic condition may have similar and up to the present time unrecognized vascular anomalies in addition. Further evidence for this conjecture is the fact that the vessels associated with the walls of congenital cysts of the lung may be hypertrophied and large in number, making the tissue extremely vascular.[42]

Moersch and Clagett[43] found that intermittent attacks of fever "were often present" in cystic disease of the lungs. They added that it is "not uncommon for such episodes to be diagnosed erroneously as pneumonia." To obviate such a mistake in diagnosis it is advisable that any patient who presents a history of intermittent episodes of fever and cough with purulent expectoration, often with pain in the thorax, should be suspected of having cystic disease of a lung. If roentgenologic examination localizes evidence of disease to a lower lobe, intralobar sequestration associated with an anomalous artery must be considered.

The pathology of intralobar sequestration makes it apparent that the only adequate treatment is lobectomy. Symptoms will usually commence within the first two decades of life. In view of the postnatal growth of pulmonary tissue by means of the addition of more alveolar units,[44, 45] a process which continues for some years, it would seem that lobectomy should, when feasible, be done without delay.

Whenever cystic disease of a lower lobe is suspected and operation is to be performed, the possibility of the presence of a large anomalous artery from the thoracic or abdominal aorta or from the celiac axis to the lower lobe must be borne in mind.

In the examination of gross specimens in cases of anomalous artery associated with bronchopulmonary sequestration, cutting the fixed pulmonary tissue into thin slabs appears to be a useful method. The relationship of tissues to each other and to the branches of the anomalous vessel are easily studied. In view of what has been postulated concerning congenital cysts and similar unrecognized vascular anomalies, it would seem profitable to use the same method for examining congenital cysts not associated with an obvious anomalous artery.

Anomalous arteries to the lower lobes of lungs make the lobe which they supply an interesting laboratory for the study of the effects of raised pressures in the pulmonary vascular system. It has been shown that in a number of cases wide vascular communications exist between the anomalous artery and the pulmonary arteries. Therefore, studies of gas tension and blood pressure by means of catheterization, roentgenoscopic study during injections of radio-

paque material, and subsequent anatomic study of the surgically removed specimens by means of the newer methods of plastic injection and corrosion, together with histologic study, would enable the correlation of physiologic, anatomic, and pathologic aspects of altered pulmonary arterial pressures.

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1950-1951

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NOTICE

The thirty-first annual meeting of The American Association for Thoracic Surgery will be held April 16, 17, and 18, 1951, in Atlantic City, New Jersey. Headquarters will be at Chalfonte-Haddon Hall.

Requests for hotel reservations should be mailed direct to Chalfonte-Haddon Hall, Atlantic City, New Jersey.

Abstracts for presentation of papers for the 1951 meeting must be received for consideration by the Program Committee on or before January 1, 1951. These abstracts should be submitted in *quadruplicate* and addressed to the Secretary of the Association, Dr. Brian Blades, George Washington University Hospital, 901 23rd Street, N.W., Washington 7, D. C. They should not be sent to the Editor. Abstracts received after January 1, 1951, will not be considered.

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